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MEASUREMENT OF THE GROWTH RATES OF *MYTILUS CALIFORNIANUS* AND *MYTILUS EDULIS* IN MONTEREY HARBOR

Robert Edward Delgado

United States
Naval Postgraduate School

THESIS

MEASUREMENT OF THE GROWTH RATES OF
MYTILUS CALIFORNIANUS AND MYTILUS EDULIS
IN MONTEREY HARBOR

by

Robert Edward Delgado

Thesis Advisor: E. C. Haderlie

September 1971

Approved for public release; distribution unlimited.

Measurement of the Growth Rates of *Mytilus californianus* and *Mytilus edulis* in Monterey Harbor

by

Robert Edward Delgado
Lieutenant, United States Naval Reserve
B. S., Louisiana State University in New Orleans, 1965

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OCEANOGRAPHY

from the

NAVAL POSTGRADUATE SCHOOL
September 1971

ABSTRACT

Measurements of the growth rates of two species of sea mussel, Mytilus californianus and Mytilus edulis, were made in Monterey Harbor during the period August 1, 1970 to August 1, 1971. Mussel populations were housed in plexiglass-stainless steel cages and exposed to intertidal and subtidal conditions. Measurements of maximum length and average volume were taken at monthly intervals throughout the annual period.

Both species had a very close correlation between sea surface temperature and growth rate and demonstrated characteristic growth patterns for each species. There existed annual, seasonal, and monthly variation in the growth rates of both species as well as differences within different ages and sizes of each species.

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ACKNOWLEDGEMENT

The author wishes to express his appreciation to Professor Eugene C. Haderlie for encouragement and guidance. Thanks are extended to Mr. Ralph V. Dykes for his warm friendship and the aid in designing the mussel cages. Appreciation is also extended to Allen K. Spaunhurst, Michael G. Spaunhurst, and Steven G. Spaunhurst for their great aid in the tedious task of data collection.

I. INTRODUCTION

Marine ecology is concerned with the interrelations between marine organisms and the environment in which they live. The recent increase in public interest in ecology, especially in pollution and the economic aspects involved, requires that there be a method to determine the quality of the environment at a given time or within a reasonable length of time. The primary objective of this research is to attempt to measure the quality of the marine environment in Monterey Harbor by measuring the growth rates of two species of sea mussel, Mytilus californianus and Mytilus edulis, over a one year period.

Initial studies on the effect of sea surface temperature, food, salinity and exposure on the growth rates of Mytilus californianus were undertaken by Coe and Fox (1942, 1943, 1944), at La Jolla, California. Coe (1945, 1946) continued the study with Mytilus edulis and was therefore able to apply similar environmental conditions to a different species of bivalve. The arrival of unprecedented numbers of Mytilus edulis in areas around La Jolla that the species had not inhabited for years suggested the possible introduction of a foreign species and/or a physiological mutation and/or hybridization with Mytilus californianus and/or environmental changes.

Recent growth rate data has been obtained as a result of studies on marine animal relationships and environmental conditions. Reish (1963) observed the succession principle on new construction at Ventura County (Port Hueneme) and Playa del Rey (Los Angeles). Harger (1967, 1968, 1970) investigated the nature of behavioral patterns of both species as well as the effect of environmental conditions on the growth rates at

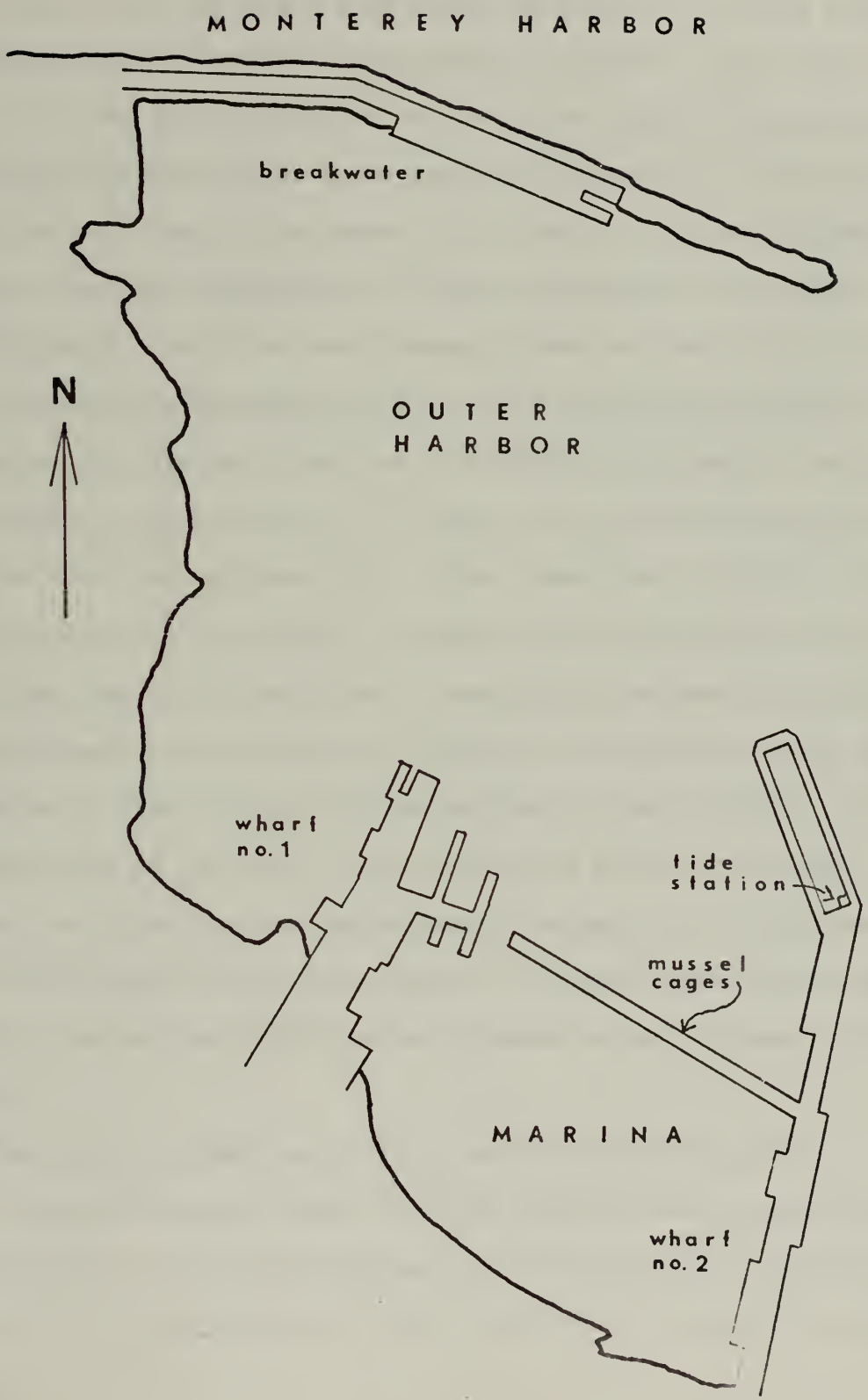
Santa Barbara, California. These studies have shown that each area has seasonal and annual variation of the growth rates of both species of sea mussel.

As far as can be determined, no systematic measurement of the growth rates of sea mussels has previously been made in Monterey Harbor. The present study includes measurement of animals in the intertidal as well as those located subtidally and includes data on both species of sea mussel.

II. AREA OF STUDY

A thorough survey of Monterey Harbor led to the choice of a site along the outer harbor side of the fishing pier extension of Wharf No. 2 (see Figure 1). This site is relatively far from local traffic within the harbor, relatively well concealed from the general public and in an area that receives adequate circulation and surf conditions to support both species. This was quite evident in that the horizontal wooden brace that lays close to the water surface in the intertidal zone supports assorted clumps of both species of mussel (see Figure 3). Also, this was the only area where both species appeared to be growing to their fullest in the harbor.

FIGURE 1


MONTEREY HARBOR
breakwater
N
OUTER HARBOR
wharf no. 1
tide station
mussel cages
MARINA
wharf no. 2

III. MATERIALS AND METHODS

Cages housed the sample populations to separate the sizes being studied, provide identical environmental conditions, and prevent possible predators such as starfish and sea otters from reaching the mussels. The cage compartments had to be large enough to hold a sample population and to be able to withstand a full year in a marine environment.

The cages were constructed of lucite (plexiglass) fused with ethylene dichloride. A stainless steel support frame was then bolted to the sides and backbone for strength (see Figure 2). Plexiglass-stainless steel construction eliminated problems of corrosion and possible interference of growth by metallic ions. The floor of the cage was permanently fused to the cubes and backbone plate. Upper covers were removable and were secured with a braided nylon lace-line passed through holes in the cover and upper portion of the cubes. Circulation holes were drilled in the compartments and were especially placed in the bottom to allow fine material to drop out and prevented silting up (Harger 1970). The circulation holes of the covers were identical to those in the bottom. The final result was that all compartments were equal in size and contained the same number of circulation holes. Each cube had 28 3/16 inch holes in both the top and the bottom for circulation and a volume of 96 cubic inches.

Each group of cages was attached to the underside of Wharf No. 2 at the location site (see Figure 3). The subtidal cage was suspended below and attached to the intertidal cage by 3/32 inch 7 x 19 lay stainless steel wire. A polypropylene safety line was also attached to each cage

FIGURE 2

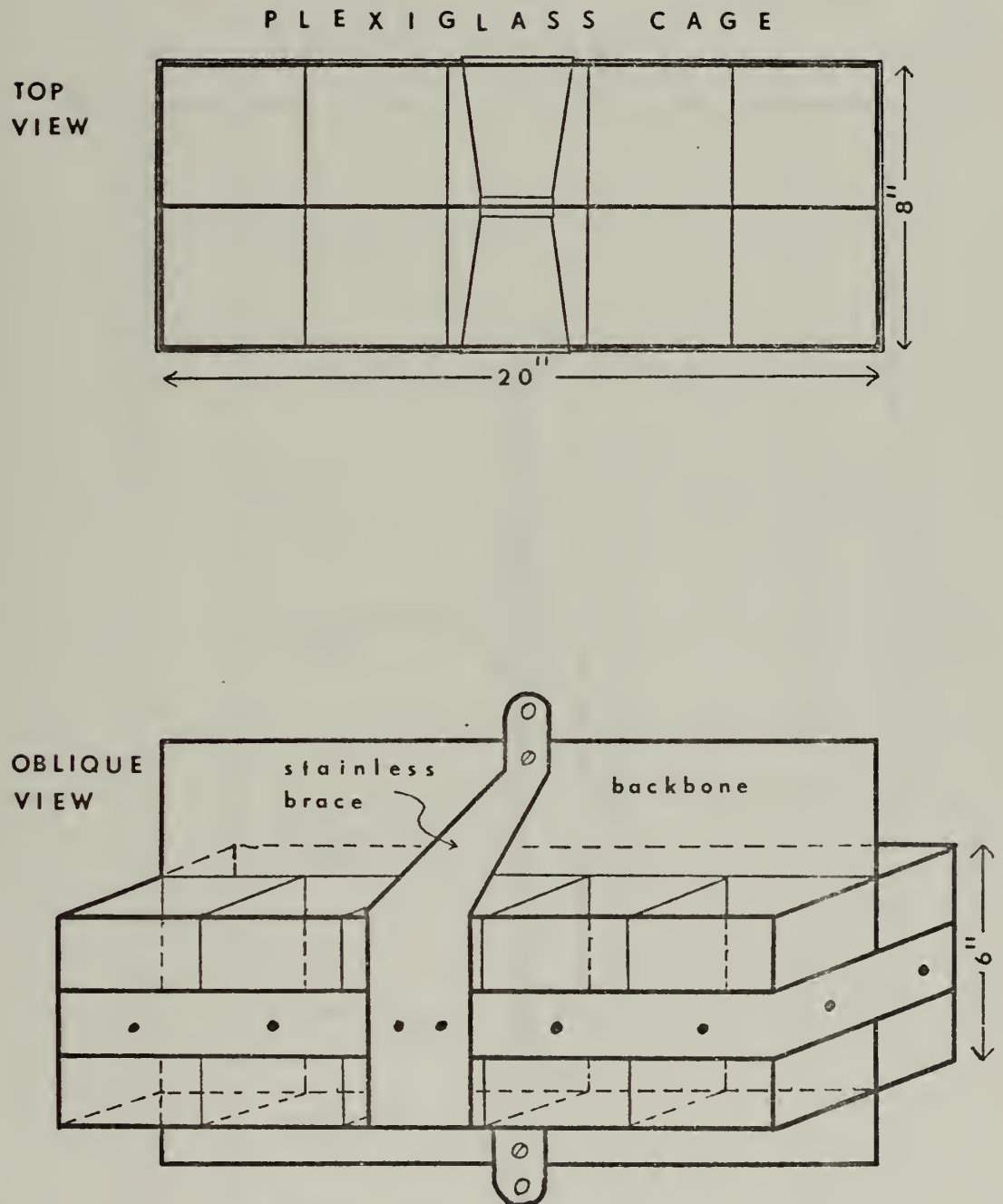
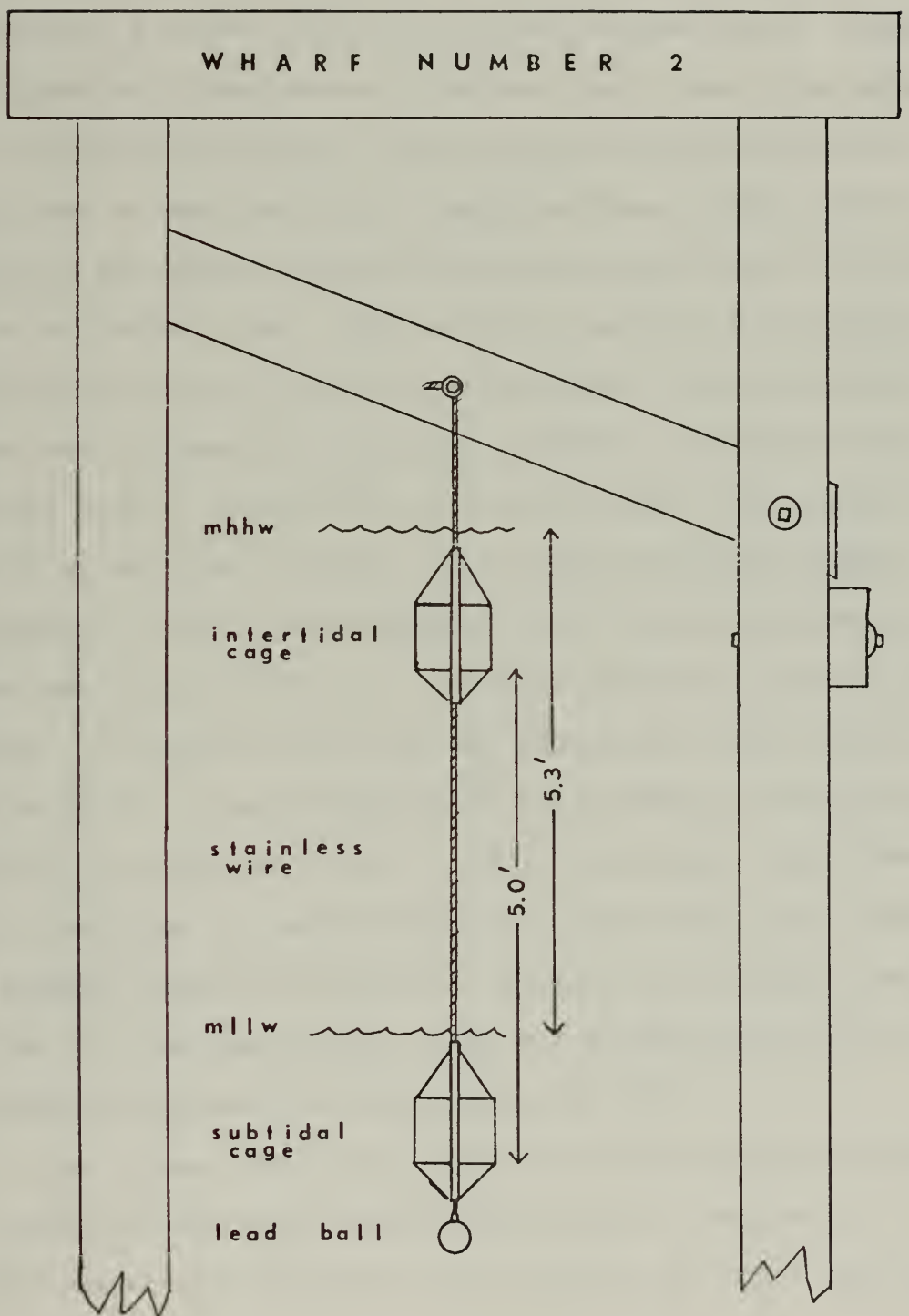

PLEXIGLASS CAGE
TOP VIEW
8"
20"
OBLIQUE VIEW
stainless brace
backbone
6"

FIGURE 3


WHARF NUMBER 2
mhhw
intertidal cage
5.3'
stainless wire
5.0'
mllw
subtidal cage
lead ball

in case of wire failure. A ten pound lead weight was attached to the bottom of the subtidal cage to dampen wave action.

Mussels used in the study were removed from their normal attached positions and taken by automobile to the laboratory where they were measured with a vernier caliper to determine maximum length. Volumes were determined by displacement. They were then placed in the cages which were taken to Wharf No. 2 where they were suspended from the lattice work as described above. Length measurements were made in mm accurate to one decimal place and volume measurements were in ml accurate to one decimal place. Since sufficient numbers of the required sizes of mussel for the study were not available locally, additional mussels were collected from Capitola, California to supplement those available locally. Those growing in Monterey Harbor only ranged to about 80 mm and 50 mm for Mytilus californianus and Mytilus edulis respectively, but the combined mussels used in the study ranged in length from 10 mm up to 100 mm. Each group was put in a separate compartment. A listing of size class and frequencies of each species is given in Table 1. Fewer large mussels were required to fill the compartments; so to prevent possible crowding, fewer large mussels were used in the study. As mussels grew into a larger class, their numbers were randomly reduced as necessary to maintain the population size of Table No. 1. The oldest groups, those that averaged greater than 100 mm in length, were discarded as they reached this size.

In order to make measurements each month it was necessary to remove the mussels from the water for approximately six to nine hours. The subtidal mussels were exposed to the air only at the time of the monthly

TABLE I

Mytilus californianus

Group #	Size Class	N
1	10 - 20 mm	20
2	20 - 30 mm	20
3	30 - 40 mm	20
4	40 - 50 mm	20
5	50 - 60 mm	15
6	60 - 70 mm	10
7	70 - 80 mm	5
8	80 - 90 mm	5
9	90 - 100 mm	5
		120

Mytilus edulis

Group #	Size Class	N
1	10 - 20 mm	20
2	20 - 30 mm	20
3	30 - 40 mm	20
4	40 - 50 mm	15
5	50 - 60 mm	3
6	60 - 70 mm	1
		79

The empirical distribution used to construct experimental mussel populations. N is the number of individuals in each size group and the total number of each species starting population is listed as the sum. Each month another group 1 was added to both species. Intertidal and subtidal populations had the same distribution.

measurements. The intertidal mussels were exposed like the natural population growing at the same tide level. The cages were repaired and cleaned thoroughly at the same time.

To insure that there was always a group of young mussels (10-20 mm group length average), new groups of both species were added to the cages each month when the data were taken.

The only physical parameter available for use in this study was sea surface temperature which was taken almost daily from the tide gage station which is located nearby on Wharf No. 2.

IV. RATE OF GROWTH

A graphical representation of the measurements of length and volume at monthly intervals appears in Appendix A. The starting size groups (10-20 mm) that were added monthly are also represented and plotted in the month they were entered.

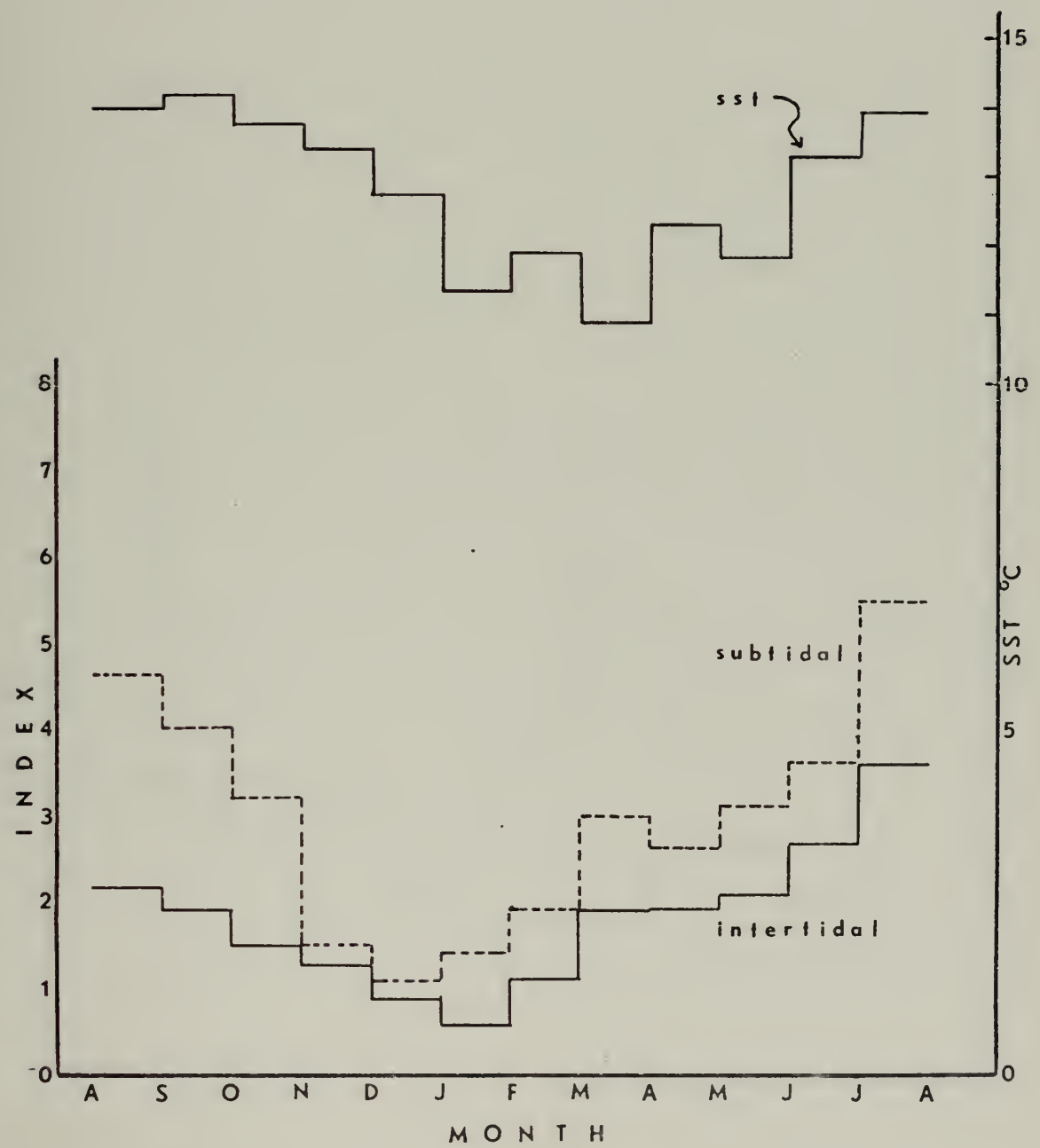
The mean increase in each species during each month of observations is compared against sea surface temperature in Figures 4 and 5. The figures were generated from the data in Appendix A. A monthly index of growth was calculated by measuring the increase in growth of all size groups and dividing by the total number of individuals of a species. This was done for the intertidal as well as the subtidally cultured mussels. The index takes into account all the individuals in the population and is considered as the average of the means of the size groups. Using this method of analysis allows the numbers to be sufficiently large to absorb individual fluctuations in growth rate (Coe 1945). The number of individuals of each species was increased by twenty each month.

The growth rates were highest during the summer months when the sea surface temperature was almost 14°C. Growth rates decreased during the Autumn months until January 1971 with the exception of Mytilus californianus intertidal. These continued to decrease in growth rate until February 1971. Then both species showed an increase in the growth index until the end of the study on August 1, 1971. There appears to be a good correlation between growth index and sea surface temperature even though the lowest sea temperature appeared in March and the lowest growth indices occurred in December 1970. The decrease in sea temperature in February may have triggered a strong growth impulse to carry

FIGURE 4

M. CALIFORNIANUS

MONTHLY GROWTH INDEX



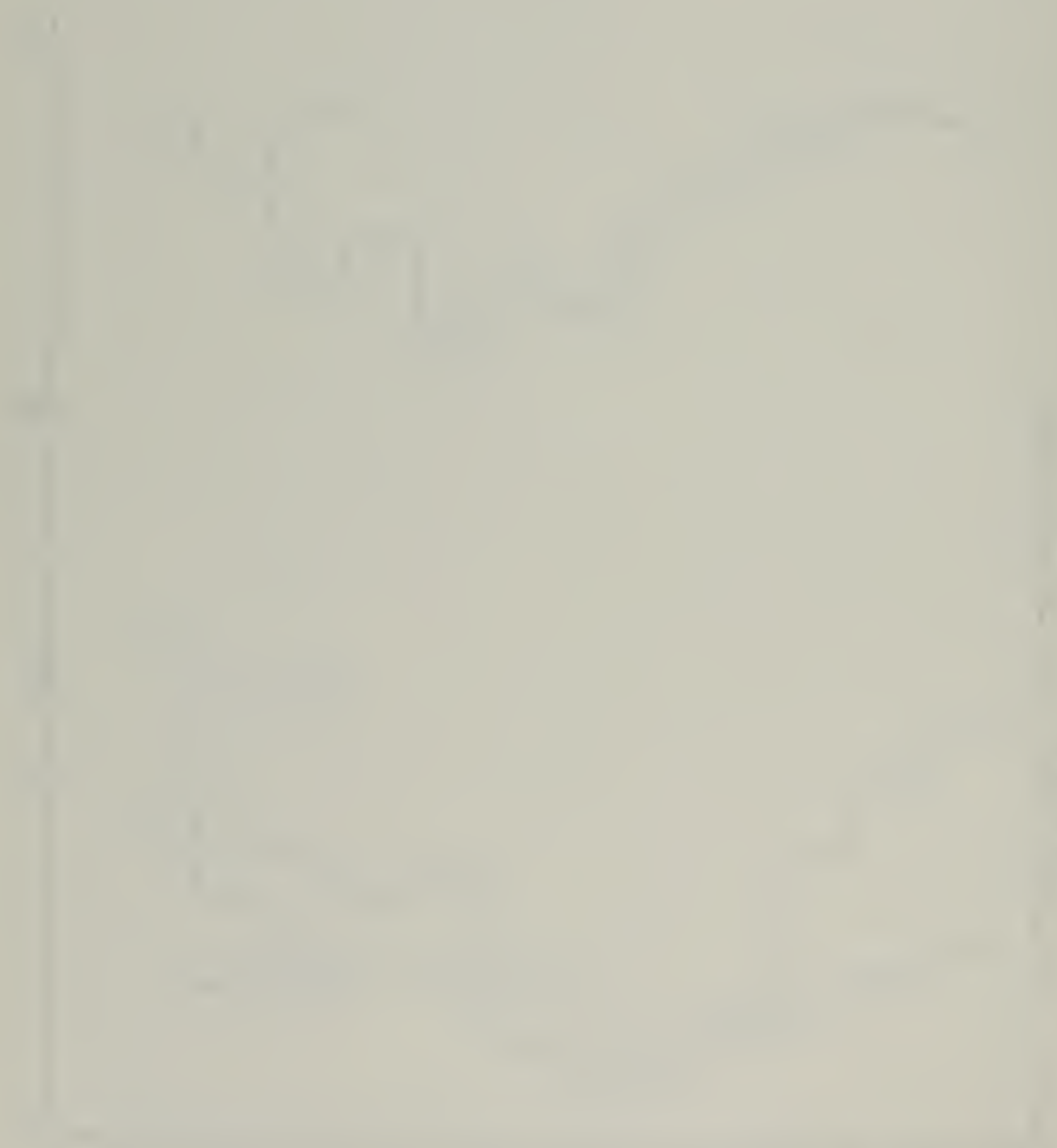
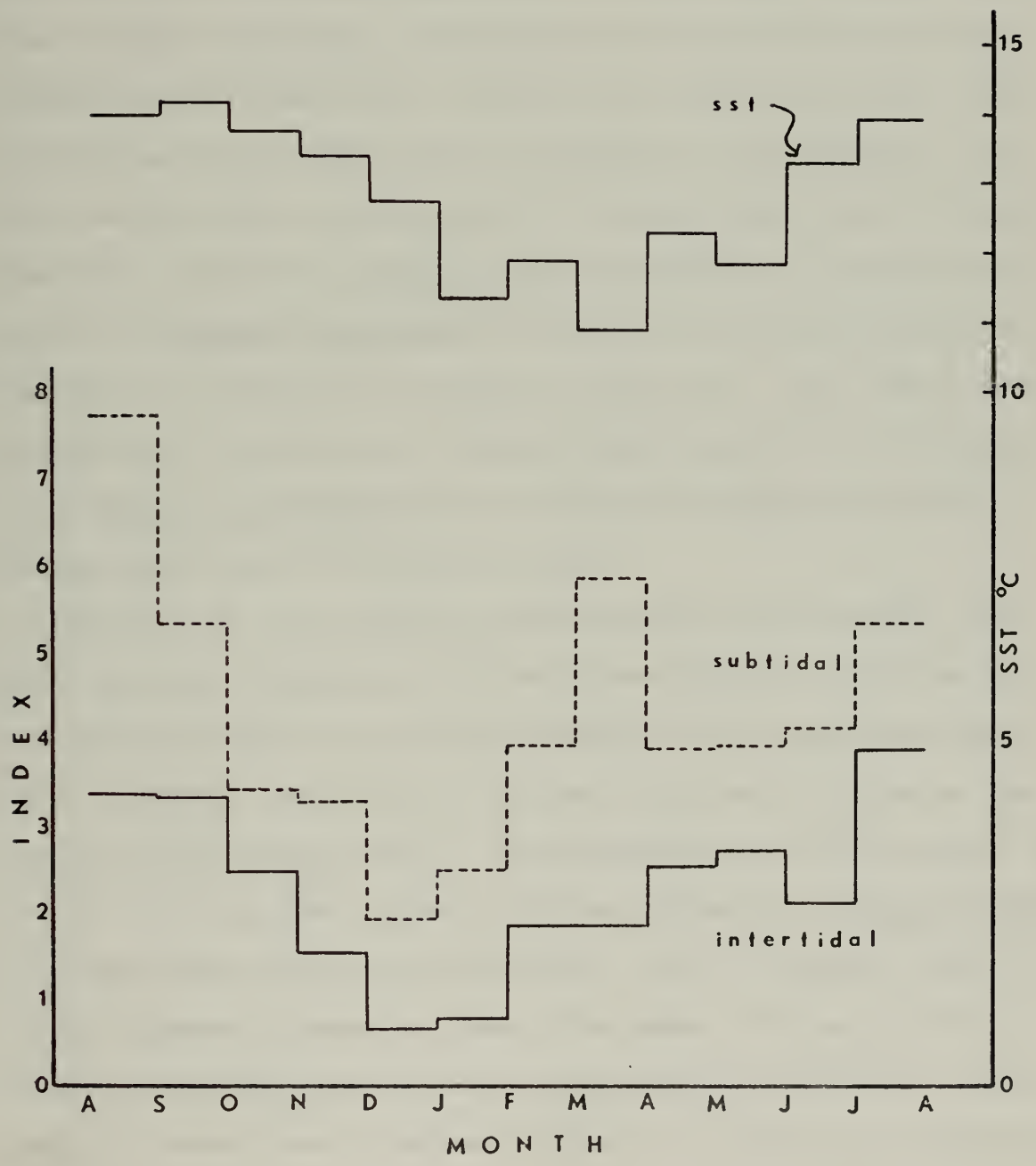


FIGURE 5

M. EDULIS

MONTHLY GROWTH INDEX



over the cooler sea temperature during March. An especially pronounced peak in growth index is seen from March to April for Mytilus edulis subtidal showing an inverse relation with sea temperature. This is probably correlated to some other environmental parameter such as food abundance and thereby demonstrating a dependance upon not sea surface temperature alone. Coe and Fox (1942) expected to find a positive correlation with sea surface temperature and growth rates in cooler regions. Their mussels demonstrated a sharp decrease in growth rate when the sea temperature was around 20°C. Also their study showed there was a close correlation between growth rates and abundance of dinoflagellates; however, mussels ingest a great variety of living and dead cells and organic particles. Subtidally, Mytilus edulis continually had a higher index of growth than Mytilus californianus throughout the year except during the last month of measurement when they were about even. This general trend may possibly be caused by the fact that since the mussels were living in cages Mytilus californianus may not have had the benefit of the full strength wave action it prefers in nature.

Figures 6 and 7 are graphical representations of each species' size class increase in length over the twelve month period. The graphs show the average length increase for the intertidal and subtidal measurement of each species. The scales are the same in all sets of graphs so that comparisons can be made easily. Here comparisons can only be made up to the 60-70 mm size group because of the non availability of Mytilus edulis in larger sizes at the onset of the study. There is a marked length increase difference between the oldest size groups (60-70 mm) and the youngest (10-20 mm) over the year of observation for both species, and a general downward trend of decreased increment in length with increasing age.

FIGURE 6

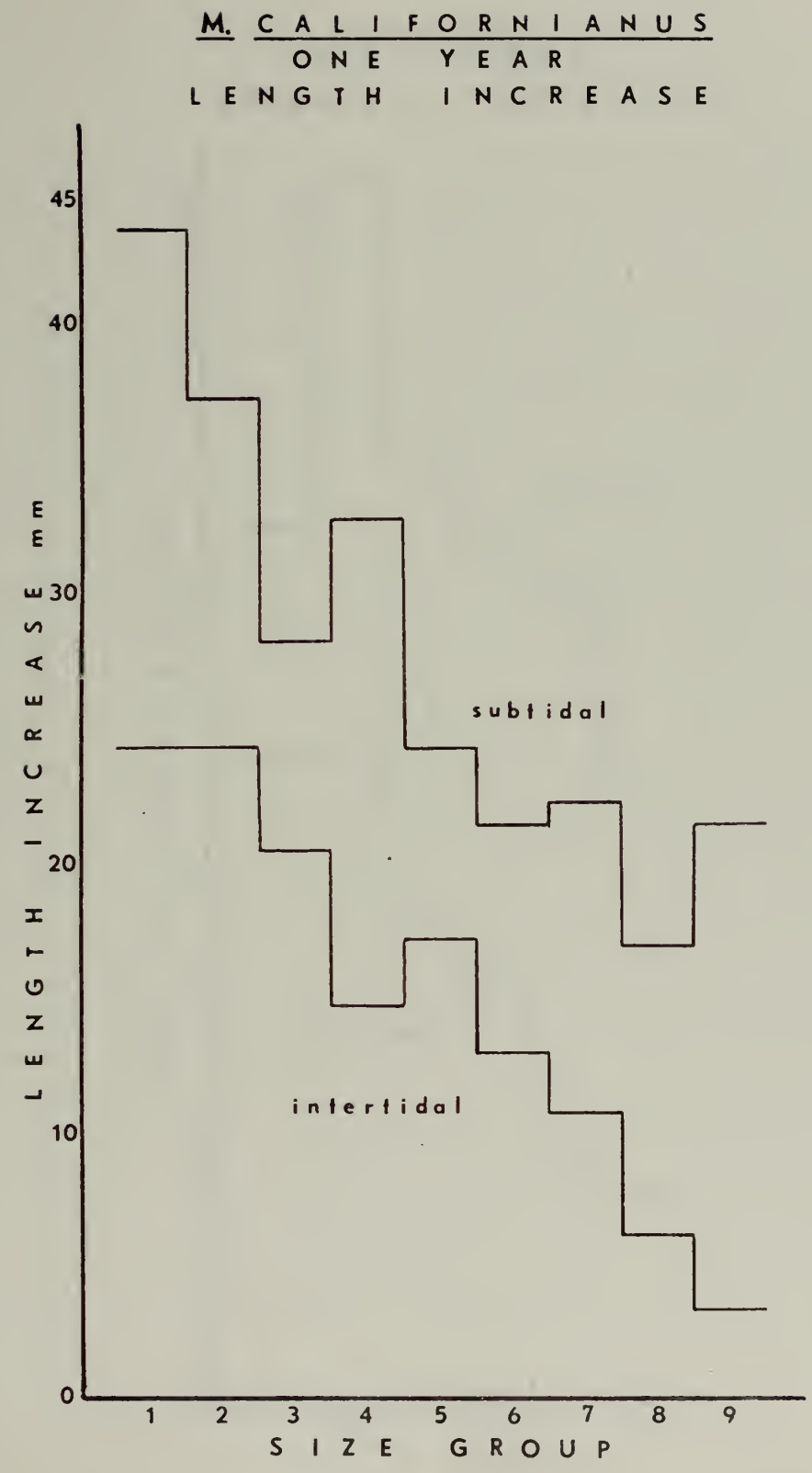
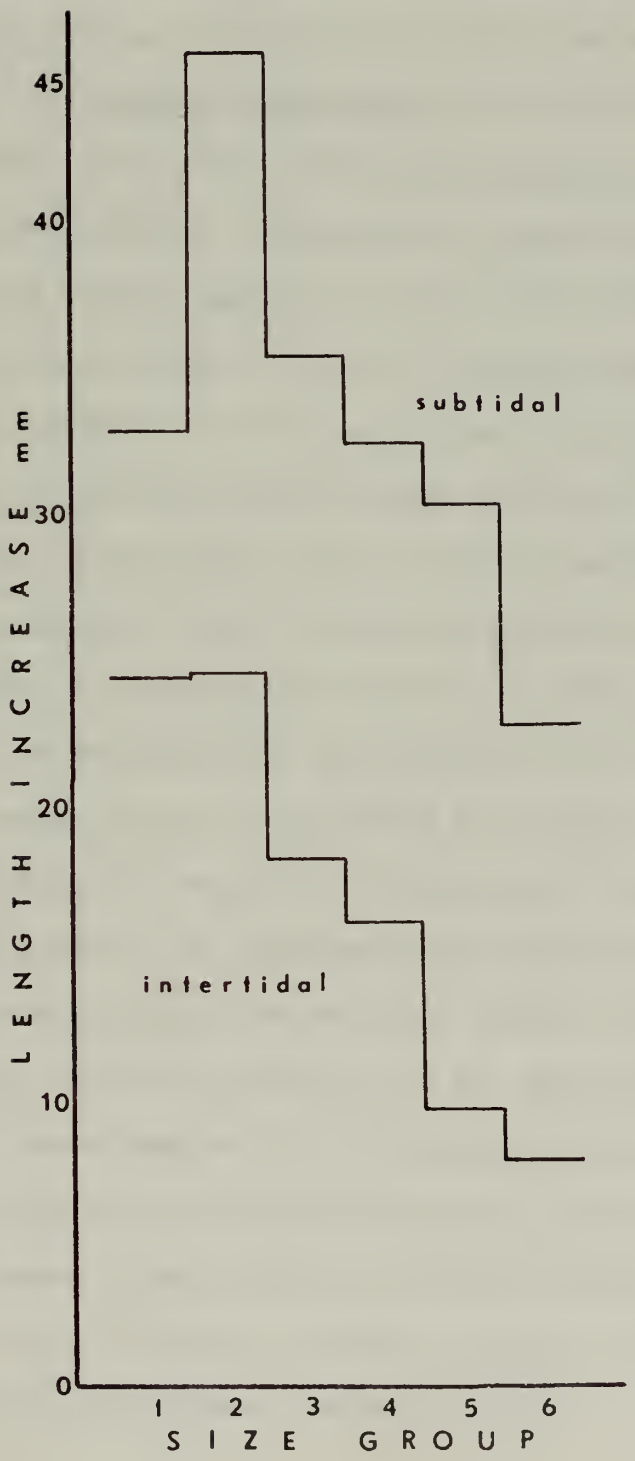

M. CALIFORNIANUS
ONE YEAR
LENGTH INCREASE
LENGTH INCREASE mm
45
40
30
20
10
0
subtidal
intertidal
1
2
3
4
5
6
7
8
9
SIZE GROUP

FIGURE 7

M. EDULIS
ONE YEAR
LENGTH INCREASE



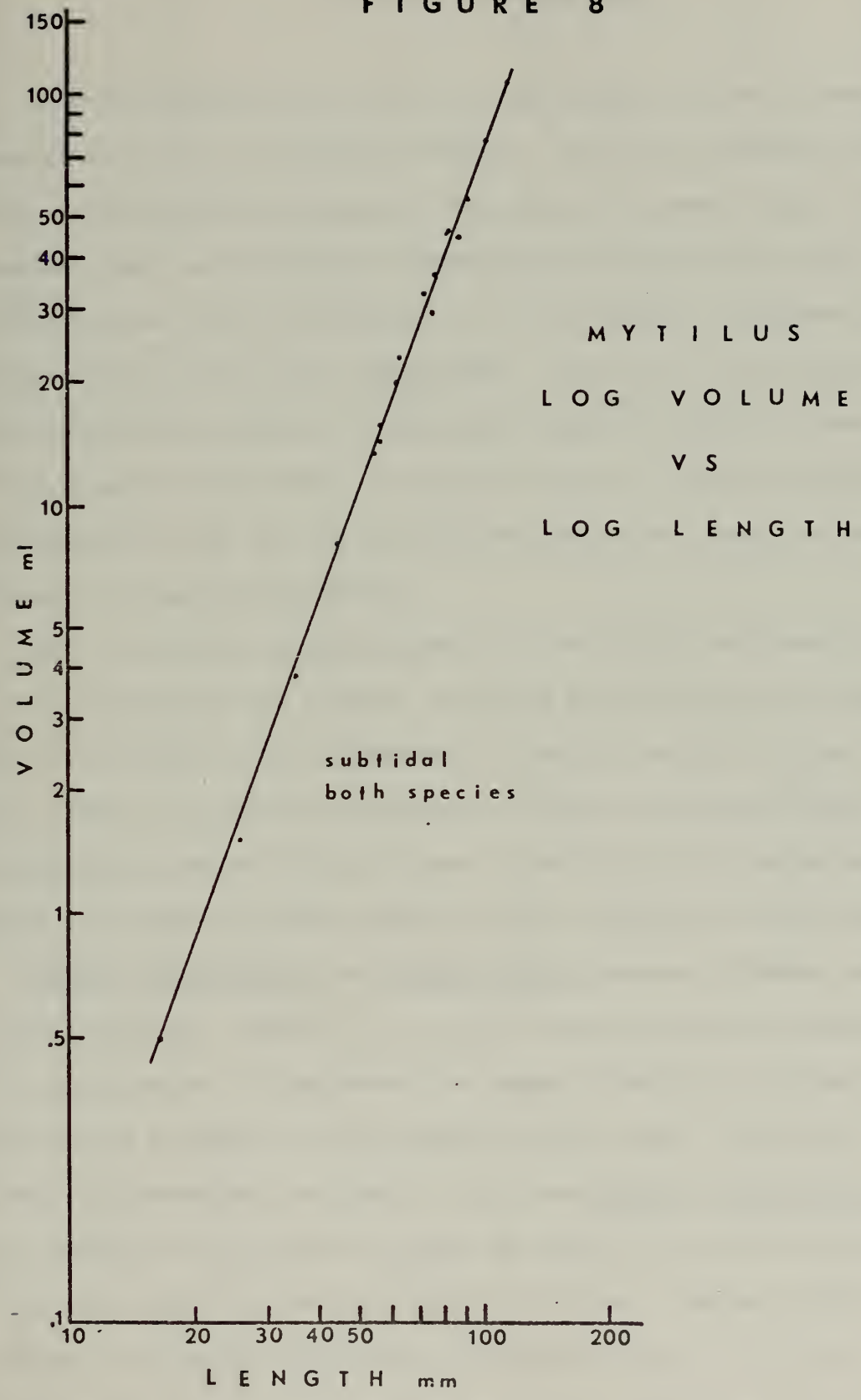
Excepting group 1, Mytilus edulis grew more than Mytilus californianus subtidally. Mytilus edulis group 2 had an 8.6 mm greater length increment than Mytilus californianus and group 3 had a 7.1 mm greater length increment. They were about equal for group 4, but group 5 again favored Mytilus edulis by 5.8 mm. Growth curves of both species prepared by Coe (1945) show that Mytilus californianus grows slower than Mytilus edulis until about eleven months when Mytilus californianus starts to grow more rapidly thereafter. Intertidally, Mytilus californianus grew more in the annual period, especially in the older groups. Both species were about equal up to groups 5 and 6 where Mytilus californianus had greater length increments of 7.6 mm and 5.2 mm respectively.

The log-log relationship between average length and average volume described by Coe and Fox (1943) existed for both species. Figure 8 is a graphical representation of this law and was generated from the subtidal data only; however, the intertidal data does fit this curve.

The growth rates measured here were enhanced by the necessity of monthly measurements because by separating the mussels from the cage one prevents the individuals from inhibiting each other's growth (Harger1970). This is generally seen in the intertidal data plots of Appendix A where the average and range spread advanced about equally from month to month.

Also, grouping was not the general rule for the intertidal mussels. This probably occurred because of the in-ability of the intertidal mussels to move about during the time that they were not covered by the tide. Subtidal mussels seemed to group very well, and the increasing spread in range seen on the data graphs is evidence of this. The same mussel is consistently the fastest or slowest growing individual in a subtidal cluster.

FIGURE 8


150
100
50
40
30
20
10
5
4
3
2
1
.5
.1
VOLUME ml
10
20
30
40
50
100
200
LENGTH mm
MYTILUS
LOG VOLUME
VS
LOG LENGTH
subtidal
both species

V. SUMMARY AND CONCLUSIONS

In environmental measurements one must realize that he is dealing with conditions that are constantly changing. There are obviously many physical and environmental parameters that affect the growth rates of sea mussels, such as sea surface temperature, salinity, wave action, ocean currents, and food concentrations. The only physical parameter used in this study was sea surface temperature. Coe and Fox (1944) found that the mussels grew fastest in times when large dinoflagellate populations were present in the water. In general there is a positive correlation between growth rates and sea surface temperature, but there are other parameters that must be considered.

The intertidally cultured mussels are definitely influenced by additional parameters, for example, length of time submerged, air temperature, relative humidity, and sun exposure to mention the most obvious. Although sea mussels are generally intertidal in nature, they grew faster and larger when cultured subtidally in cages. Possibly this resulted because a cage environment provided protection from predators and tidal exposure.

Mytilus californianus and Mytilus edulis possess different growth characteristics. Figures 4, 5, 6, and 7 show the growth characteristics for each species. As expected, the younger (smaller) individuals showed a more rapid increment in length than the older ones. Subtidally, over the year of observation, the group 1 (10-20 mm) Mytilus californianus increased its average length by 43.5 mm where the group 9 (90-100 mm) individuals only increased their average length by 21.5 mm. Similar results were observed with Mytilus edulis where the subtidal group 2 (20-30 mm) increased its average length by 45.7 mm and the group 6 (60-70 mm) only increased its average length by 22.7 mm over the one year period.

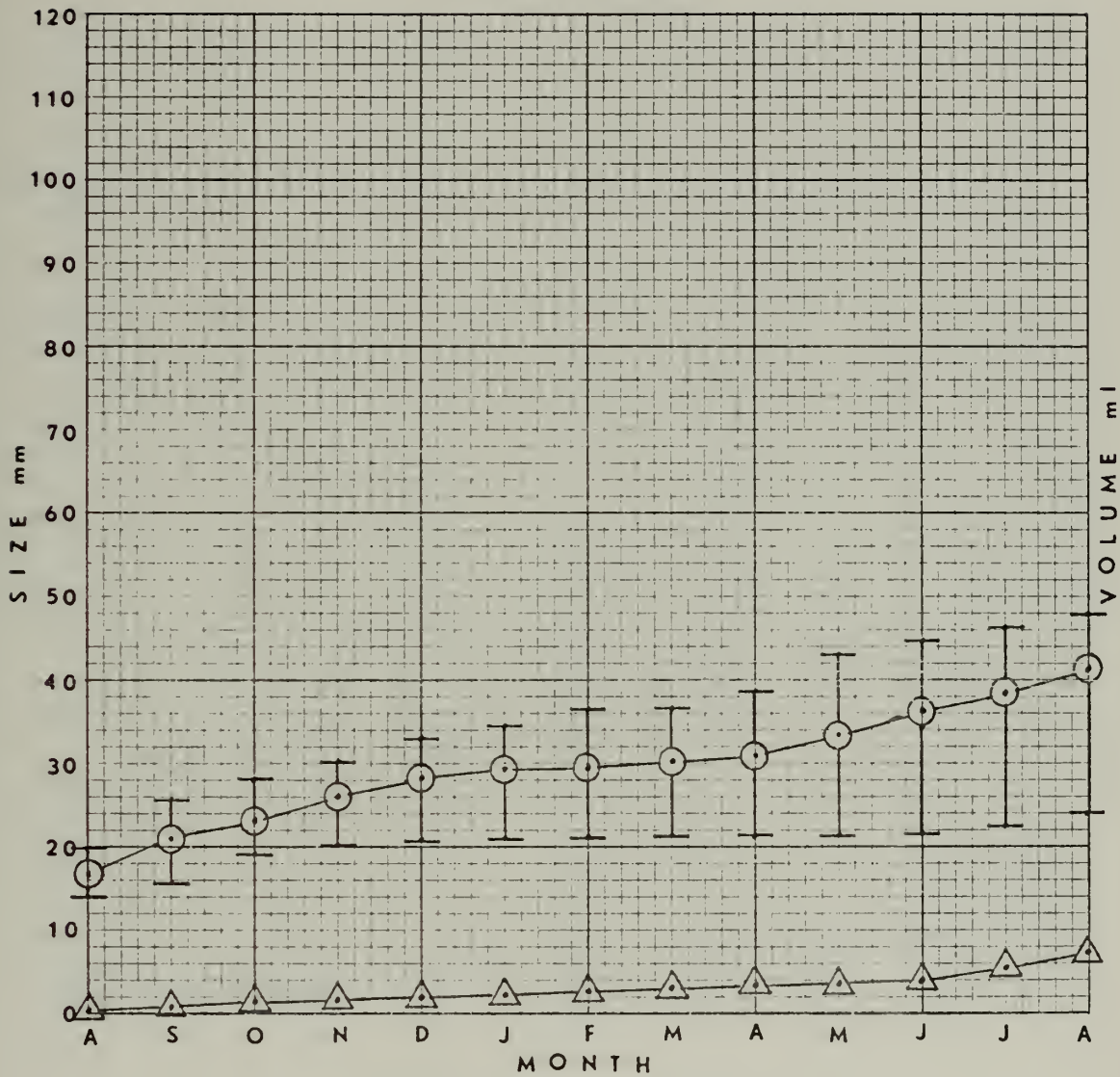
Growth increment was lowest during the winter and highest during the summer. However, there is not only this seasonal variation but monthly and annual variation in growth rates. Therefore, this study only represents the rate of growth from August 1, 1970 to August 1, 1971 and may vary for a different year.

Further studies should include measurements of other physical and biological parameters such as food, salinity, surf conditions, tidal exposure, and biological interrelationships with other shell bearing and fouling organisms that are members of the harbor community.

APPENDIX A

M. californianus

INTERTIDAL

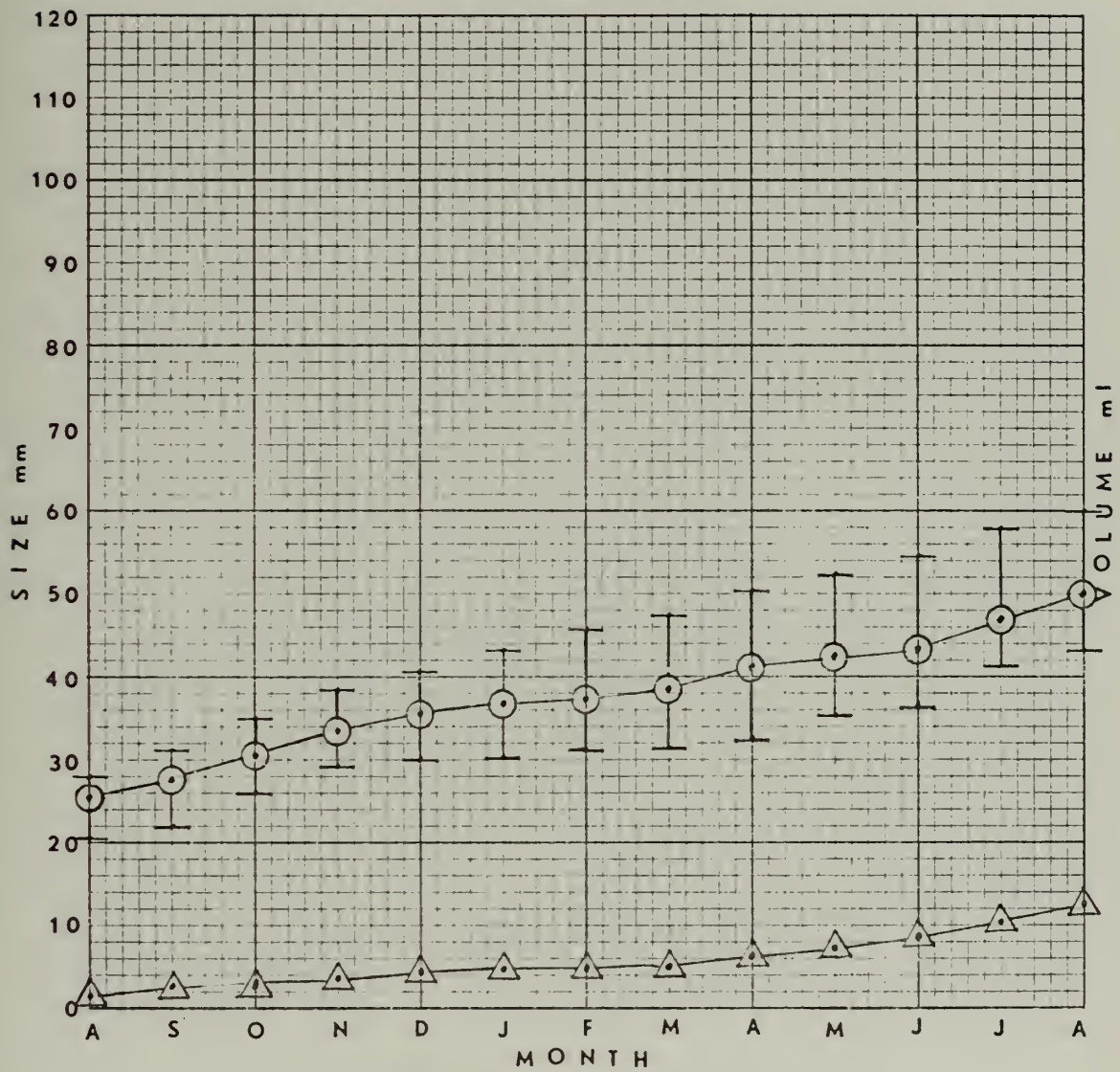


GROWTH FLUCTUATION FOR MUSSELS
SET IN CAGES AT MONTEREY HARBOR

The mean size and mean volume are recorded at monthly intervals from August, 1970 to August, 1971. The mean size is represented by circled points and the mean volume is represented by a triangle with a dot in the center. The range of size is represented by a bar on each side of the average size.

M. californianus

INTERTIDAL



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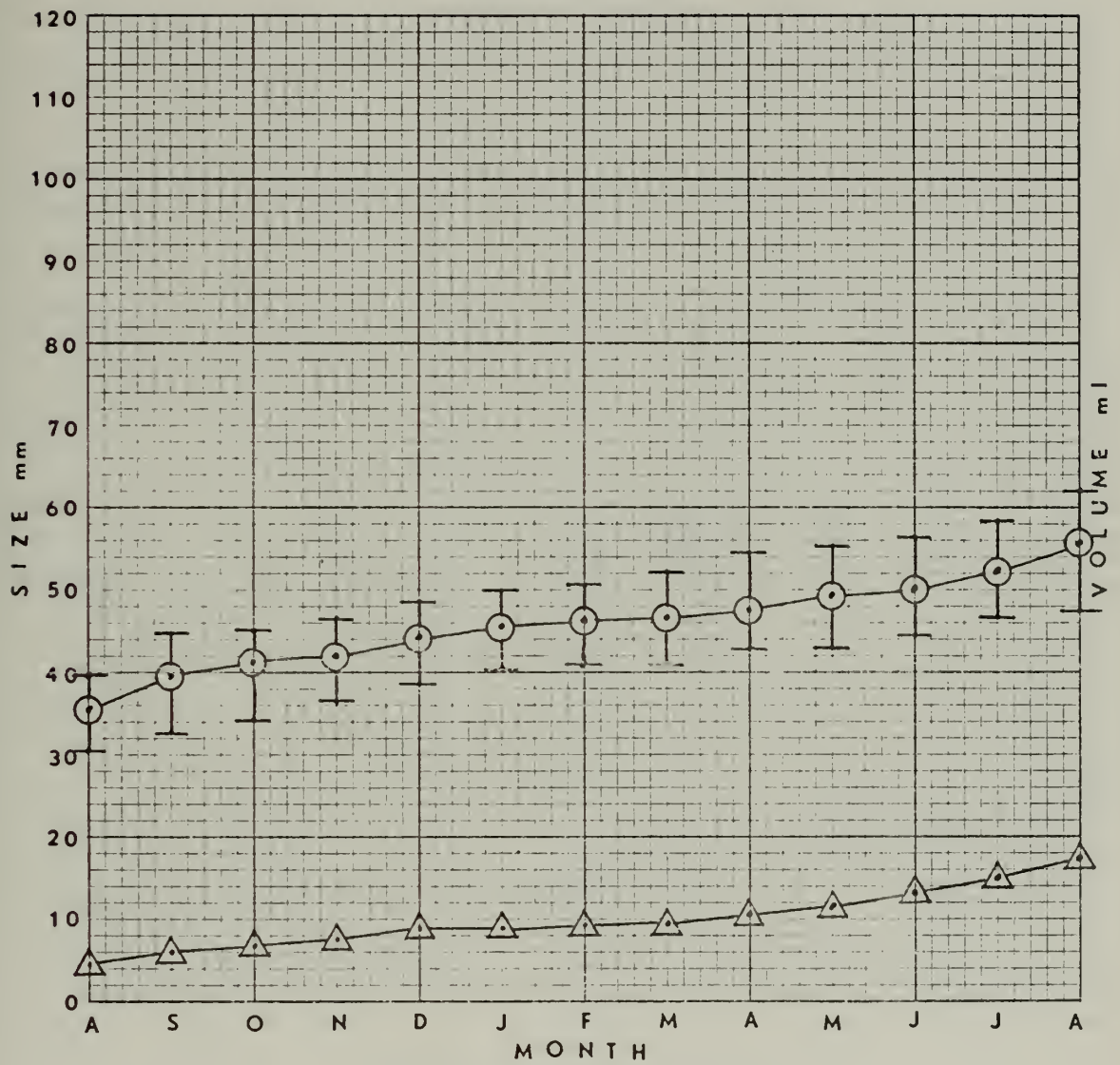
M. californianus

INTERTIDAL



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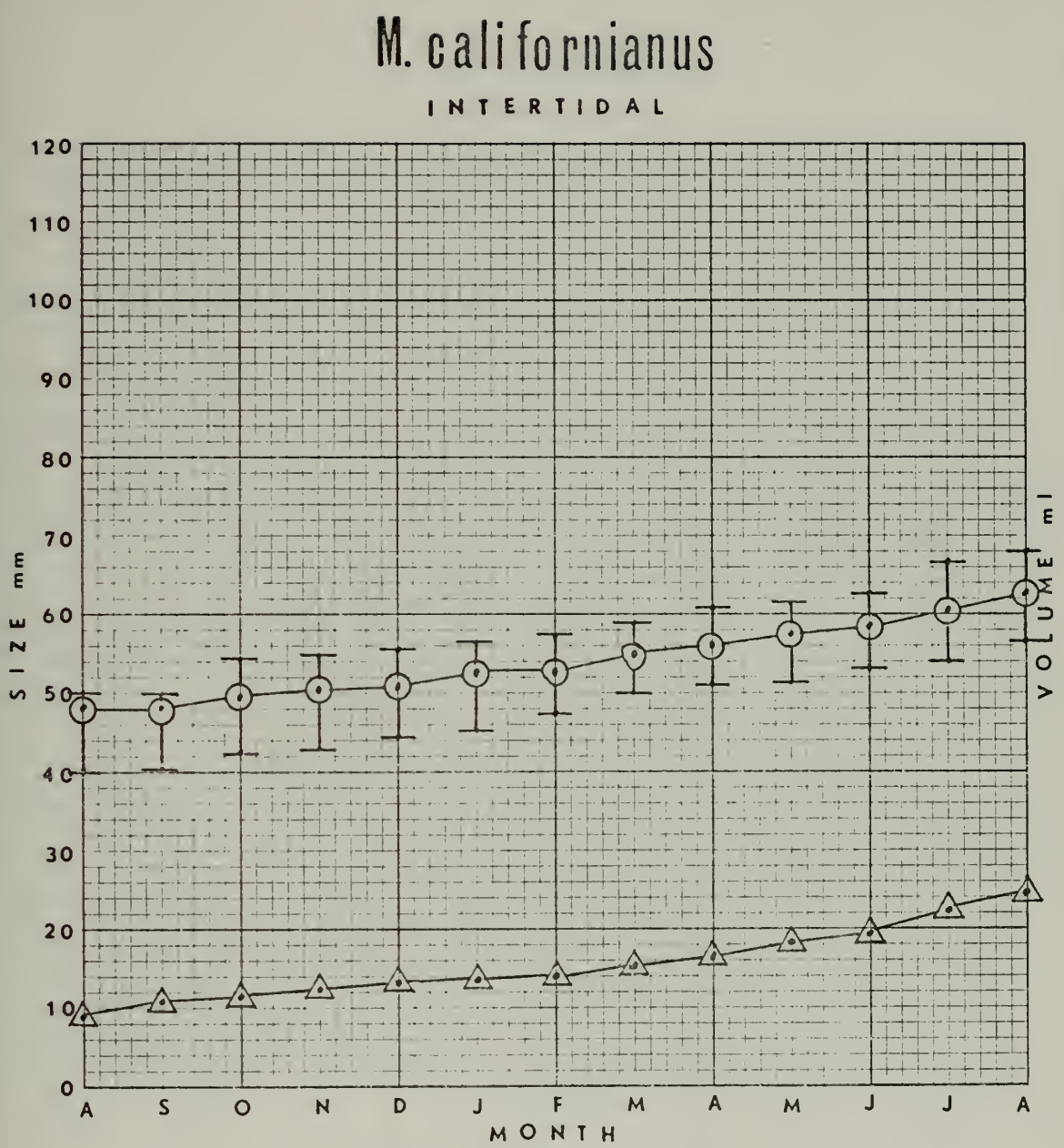

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M. californianus

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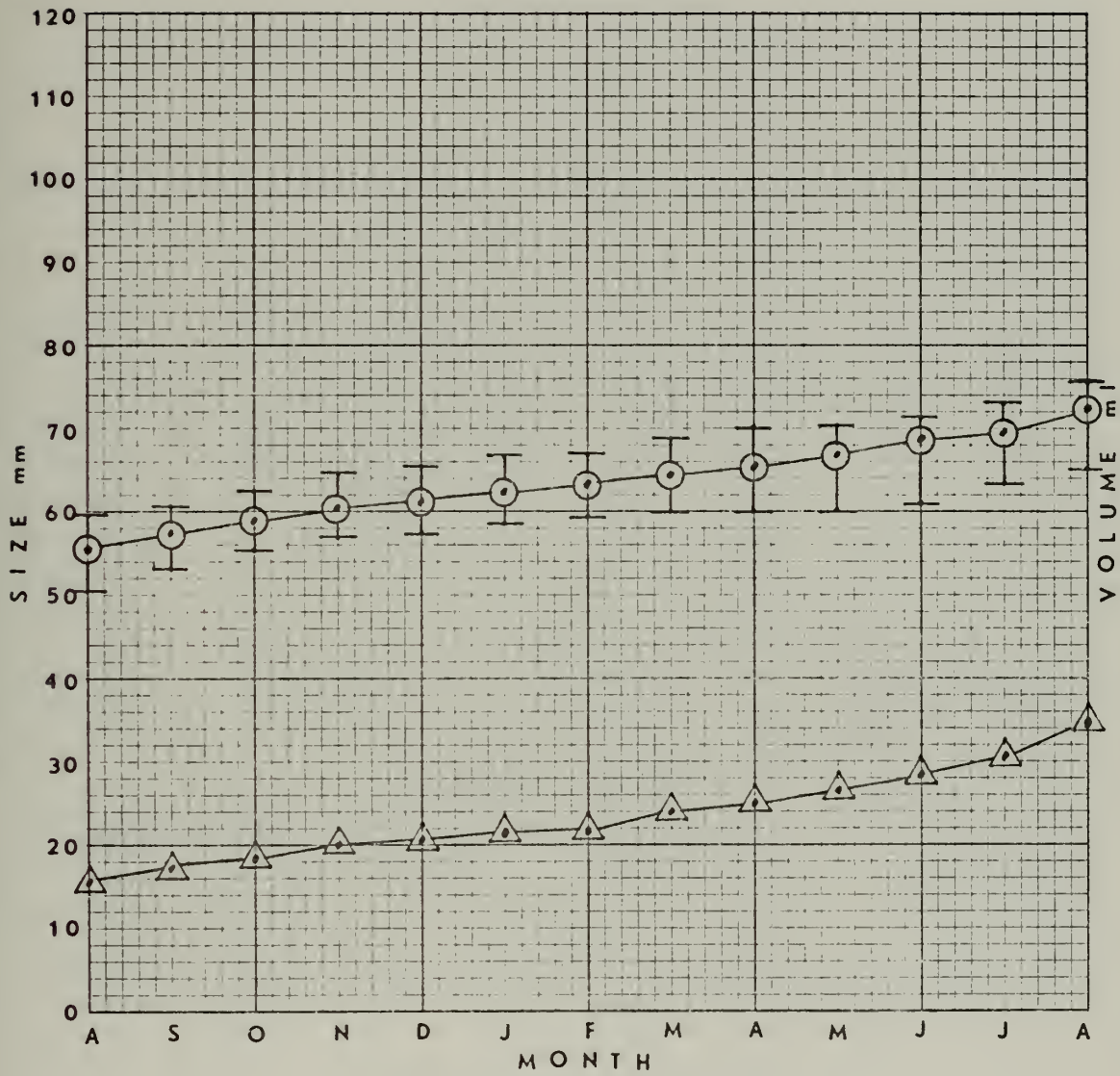

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M. californianus

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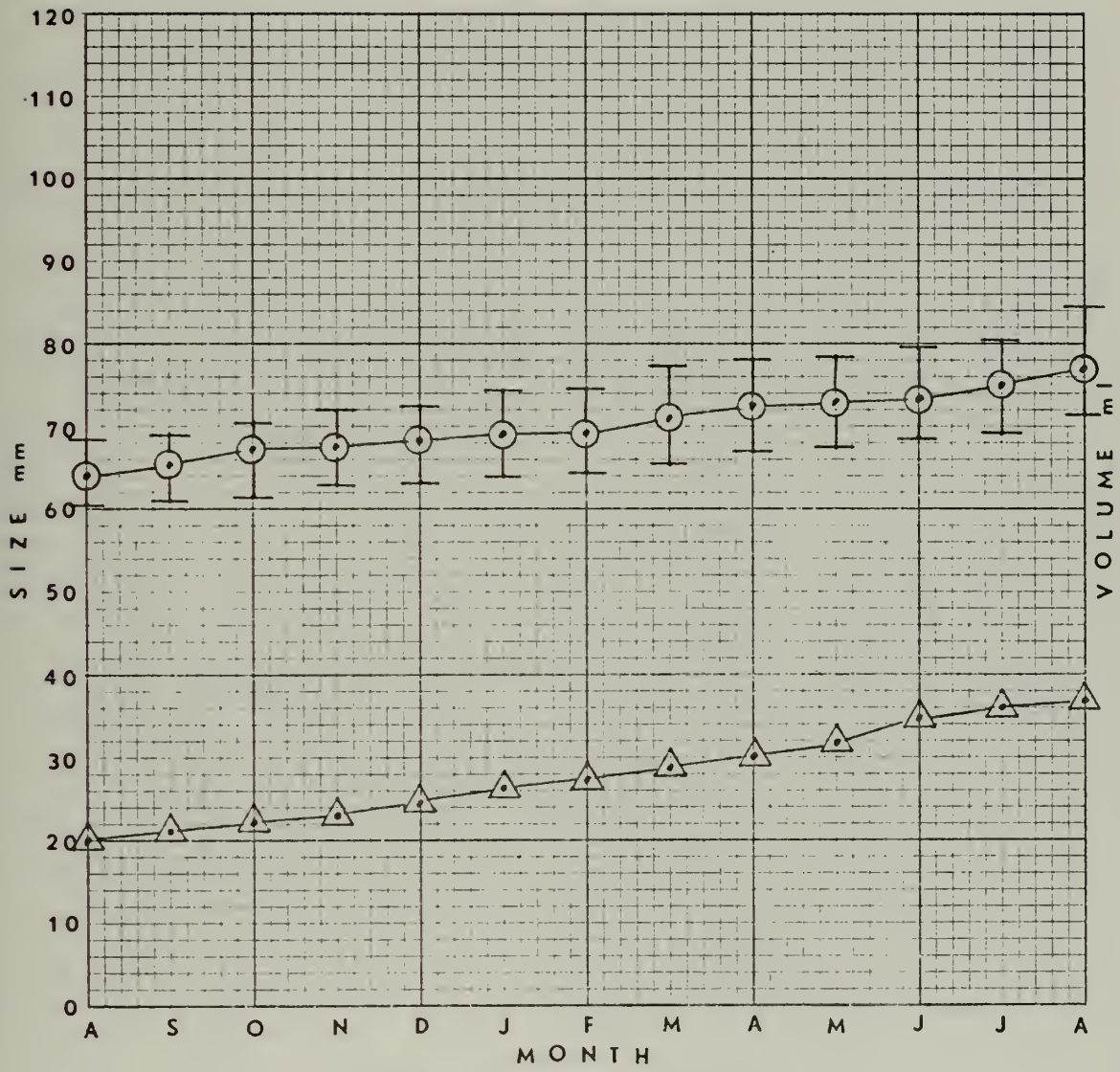

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SET IN CAGES AT MONTEREY HARBOR

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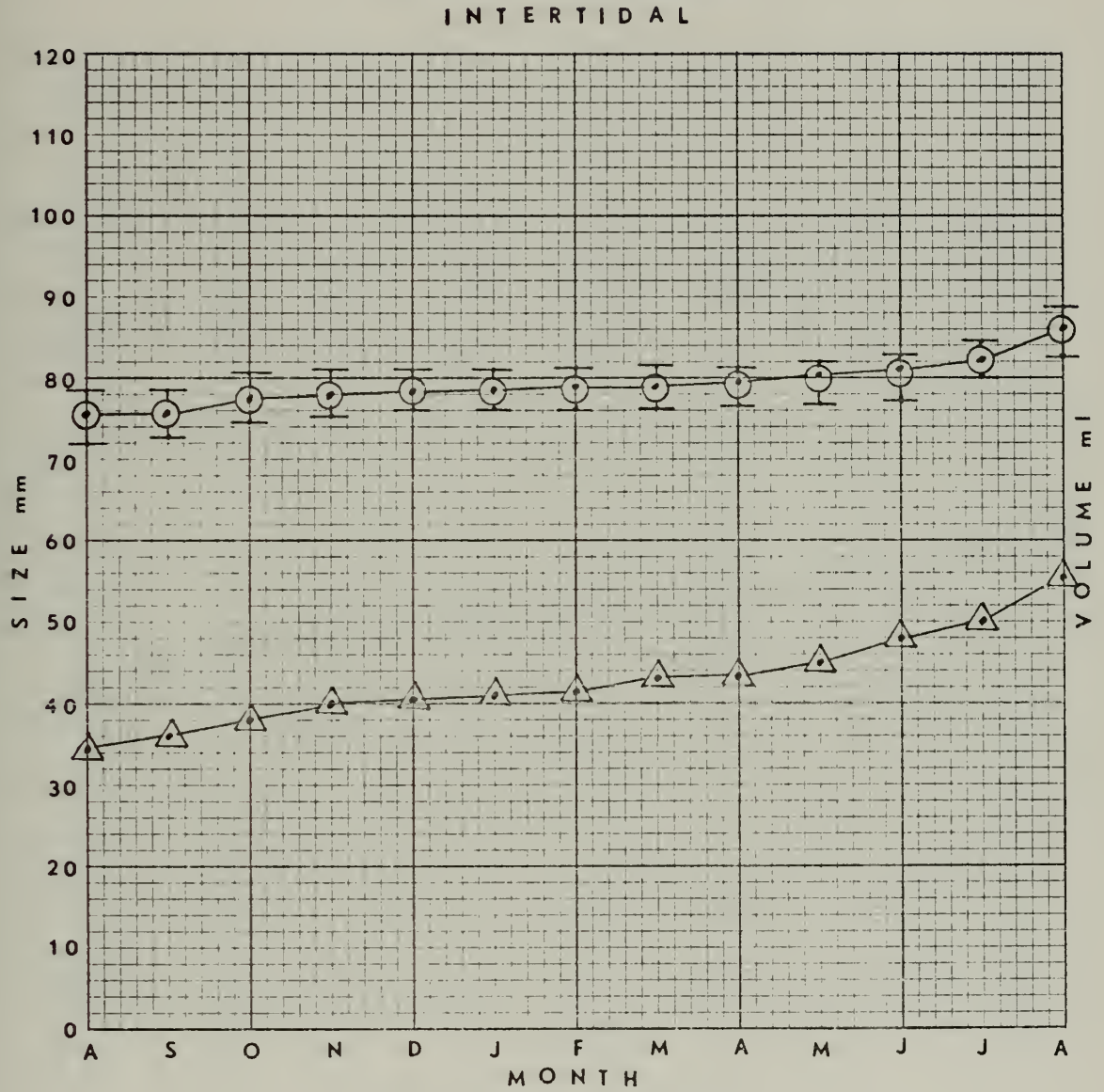

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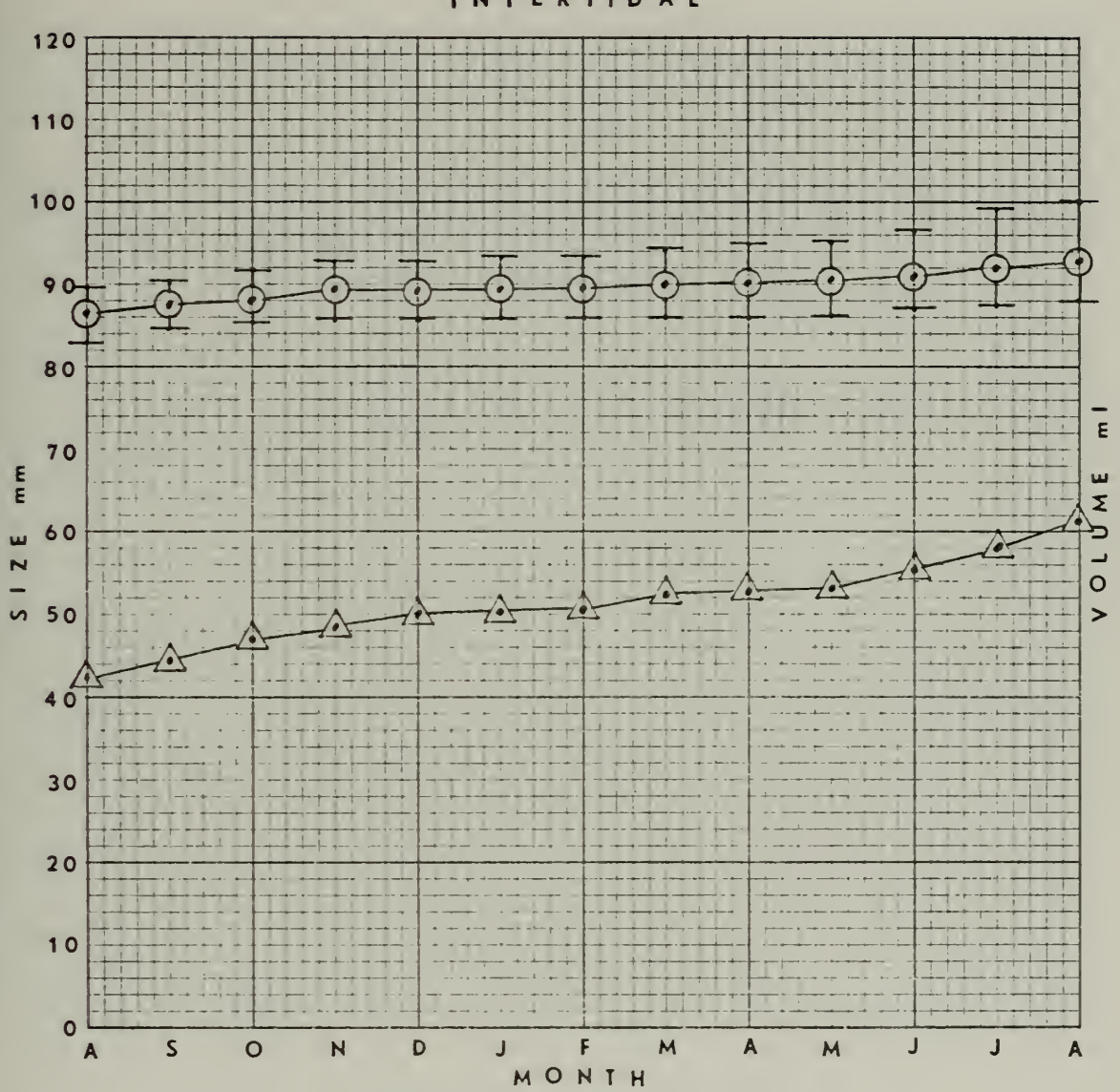

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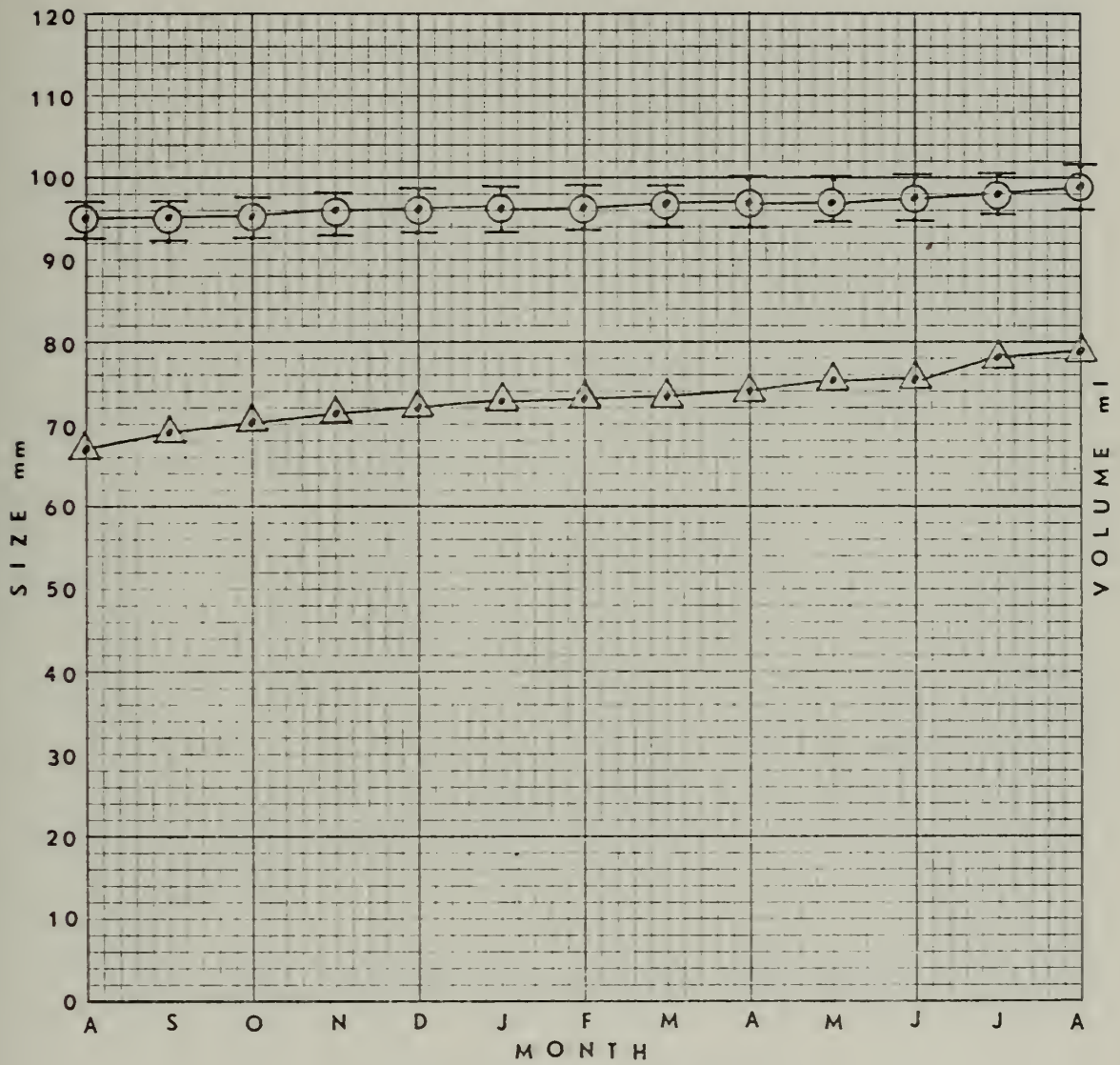
M. californianus

INTERTIDAL



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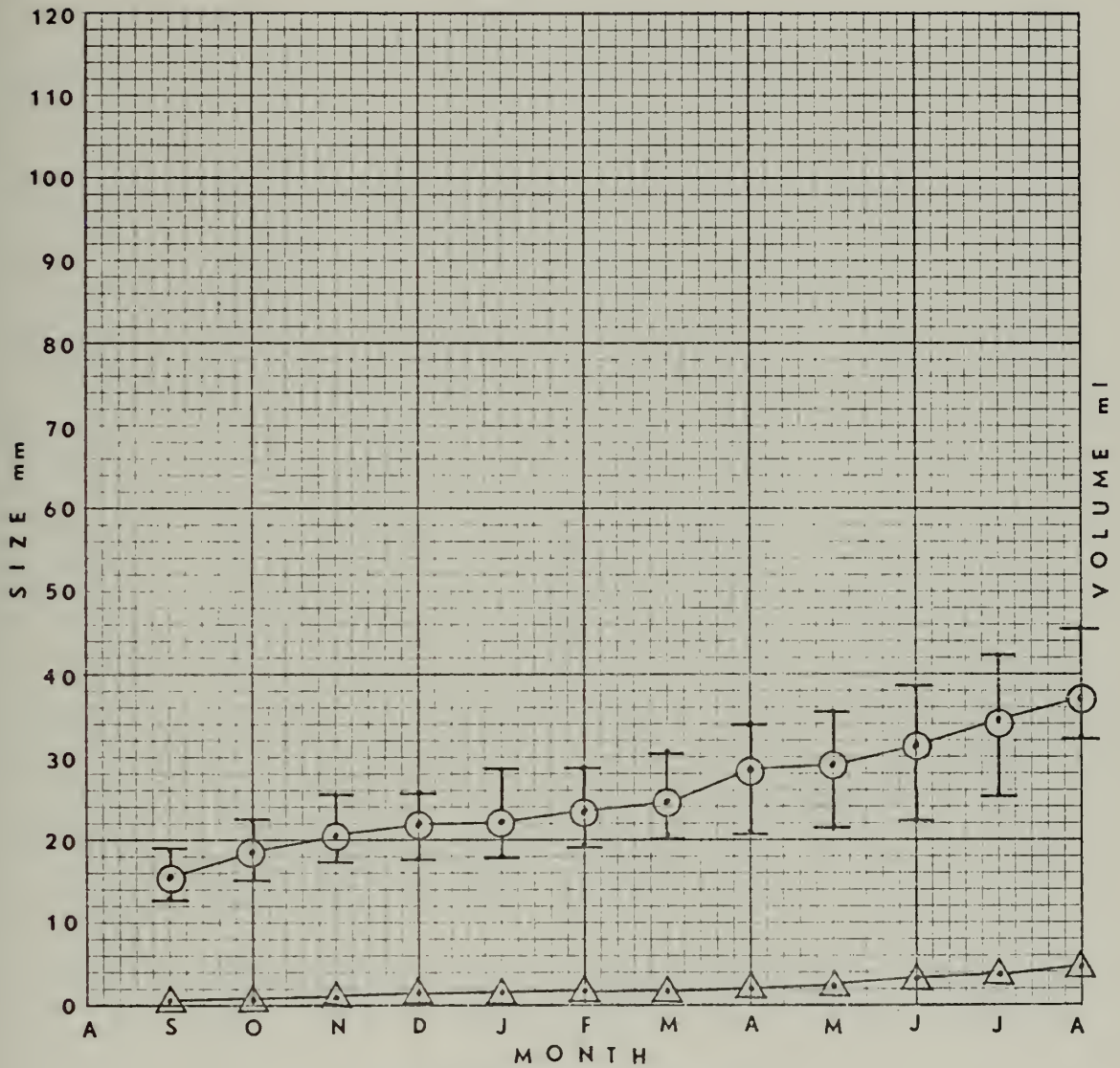

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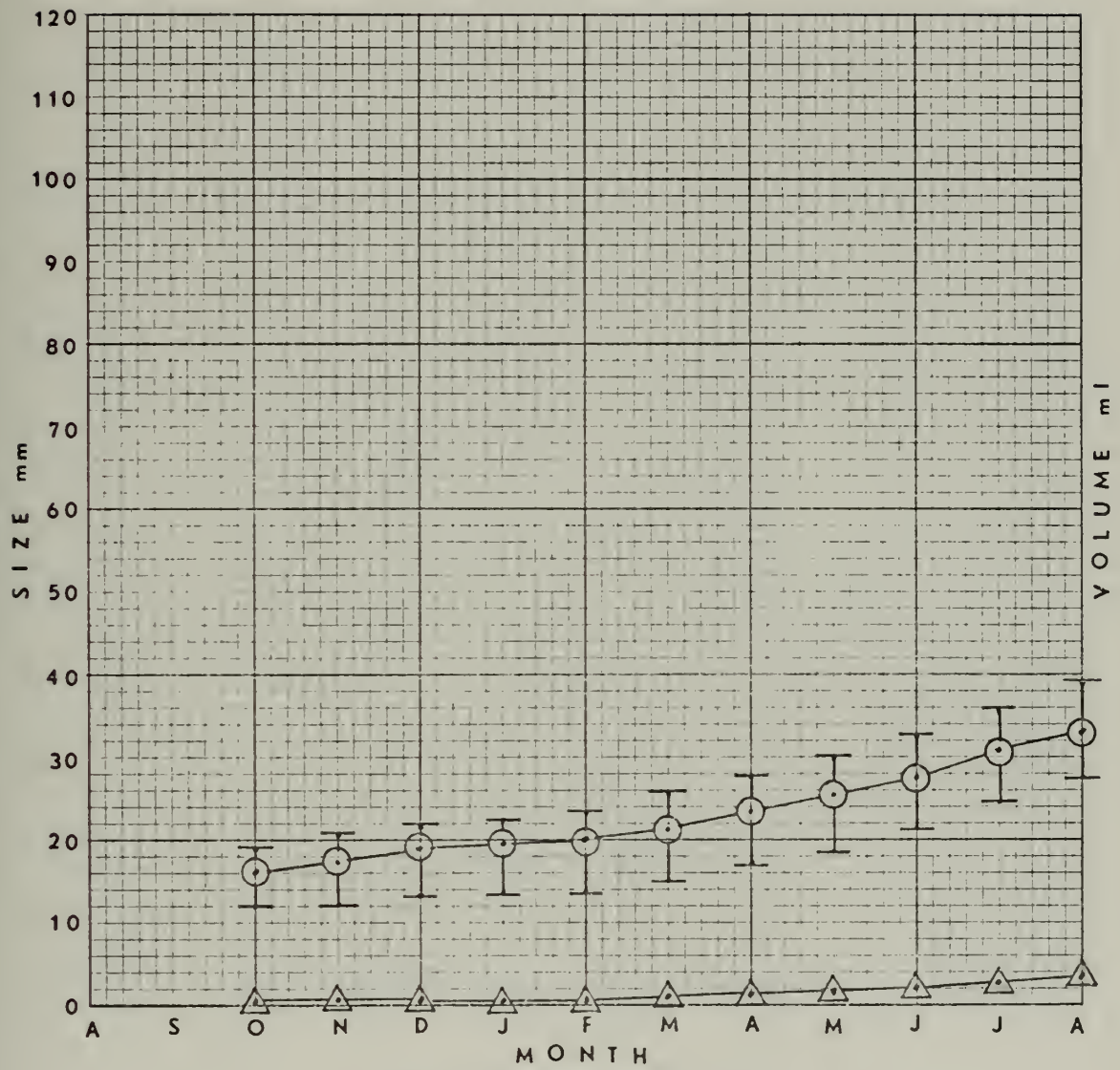

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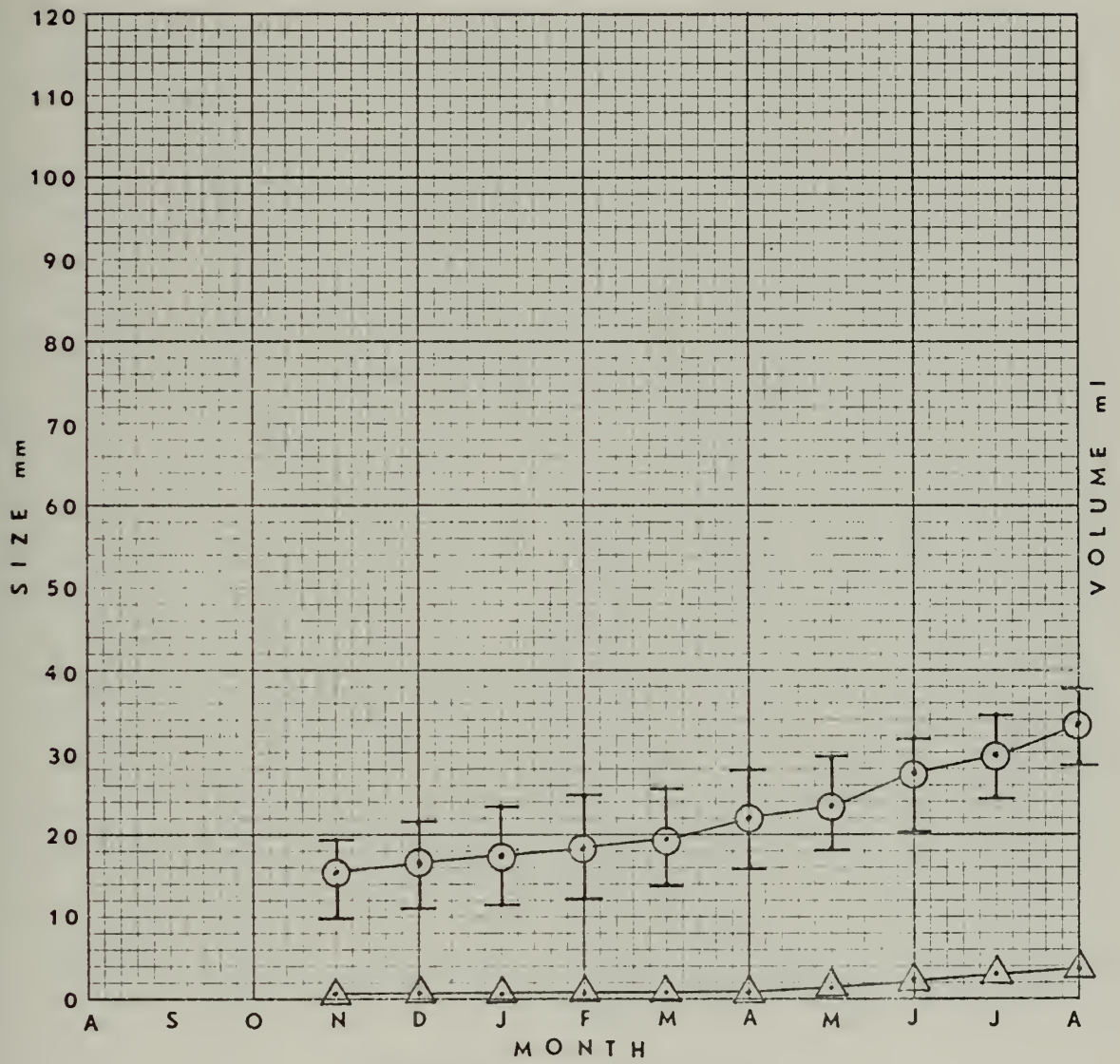

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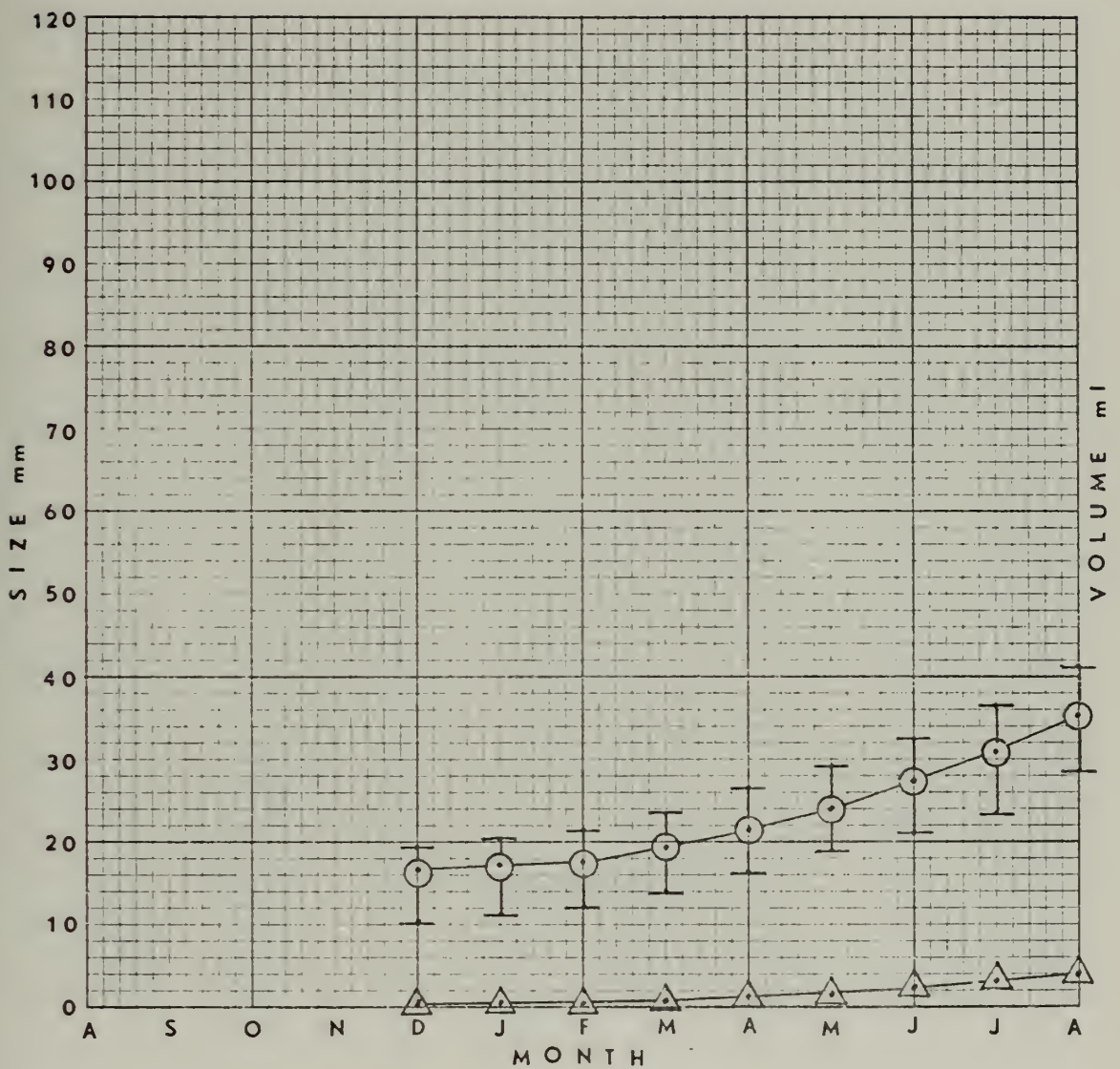

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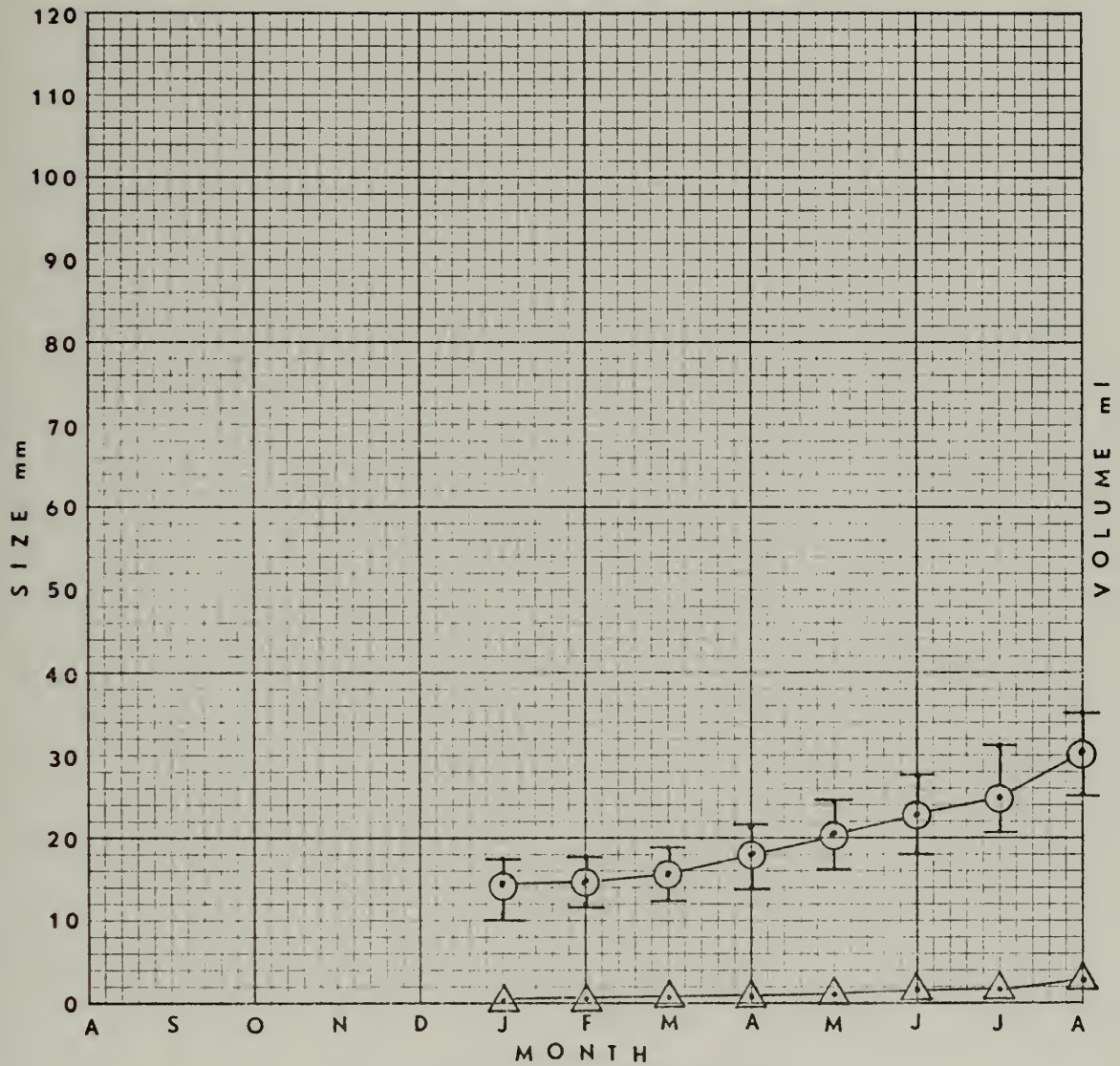

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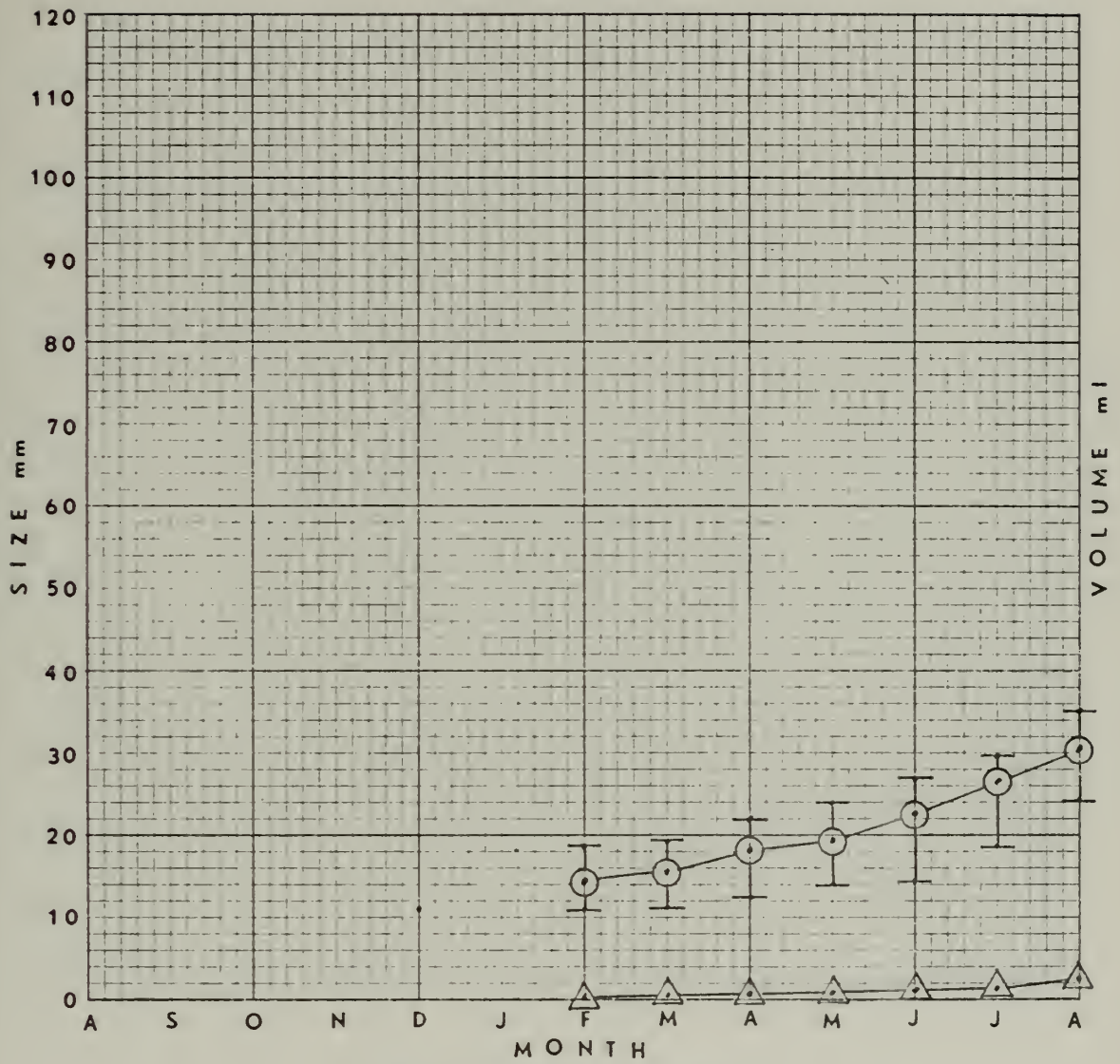

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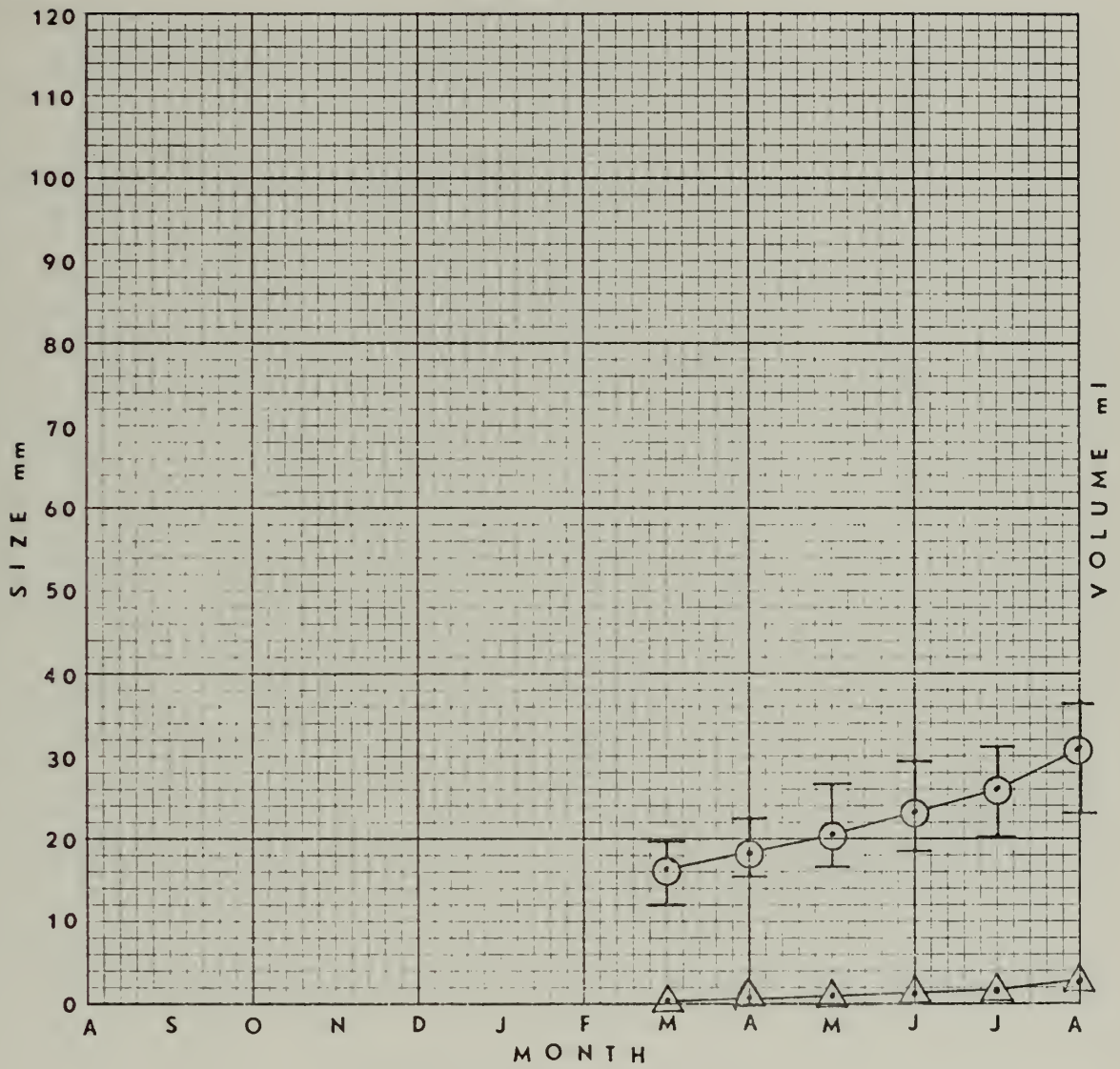

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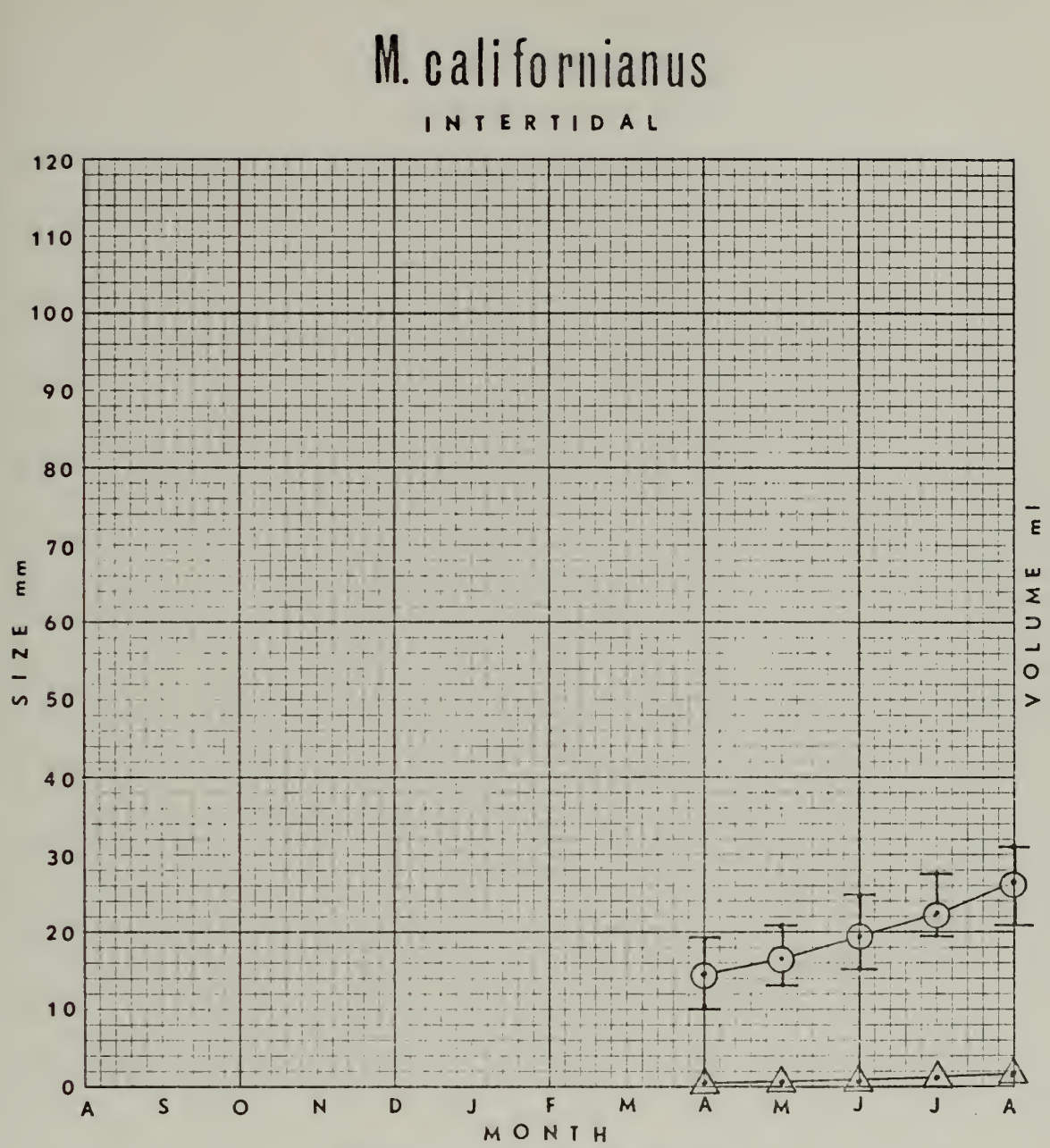

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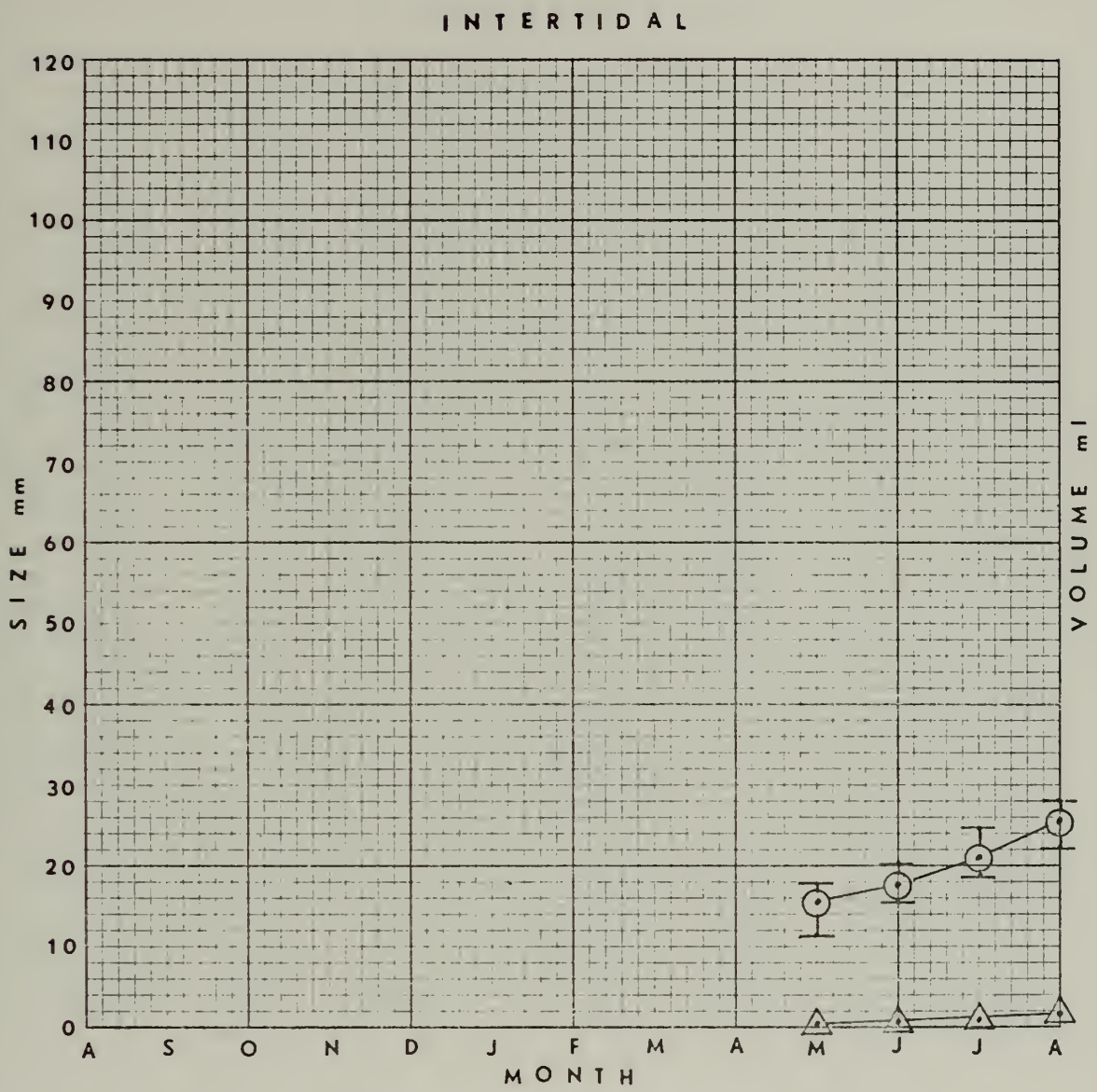

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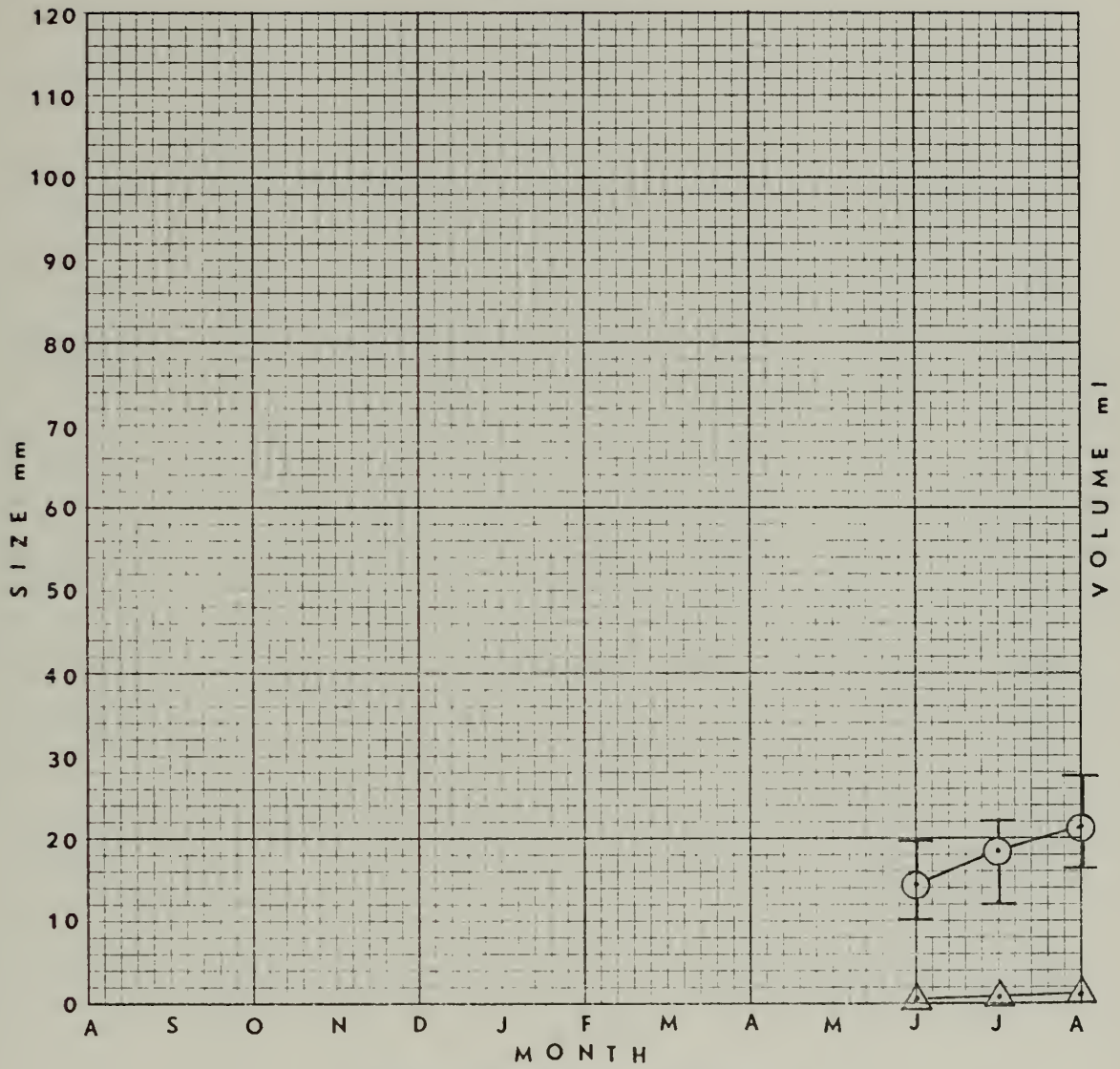

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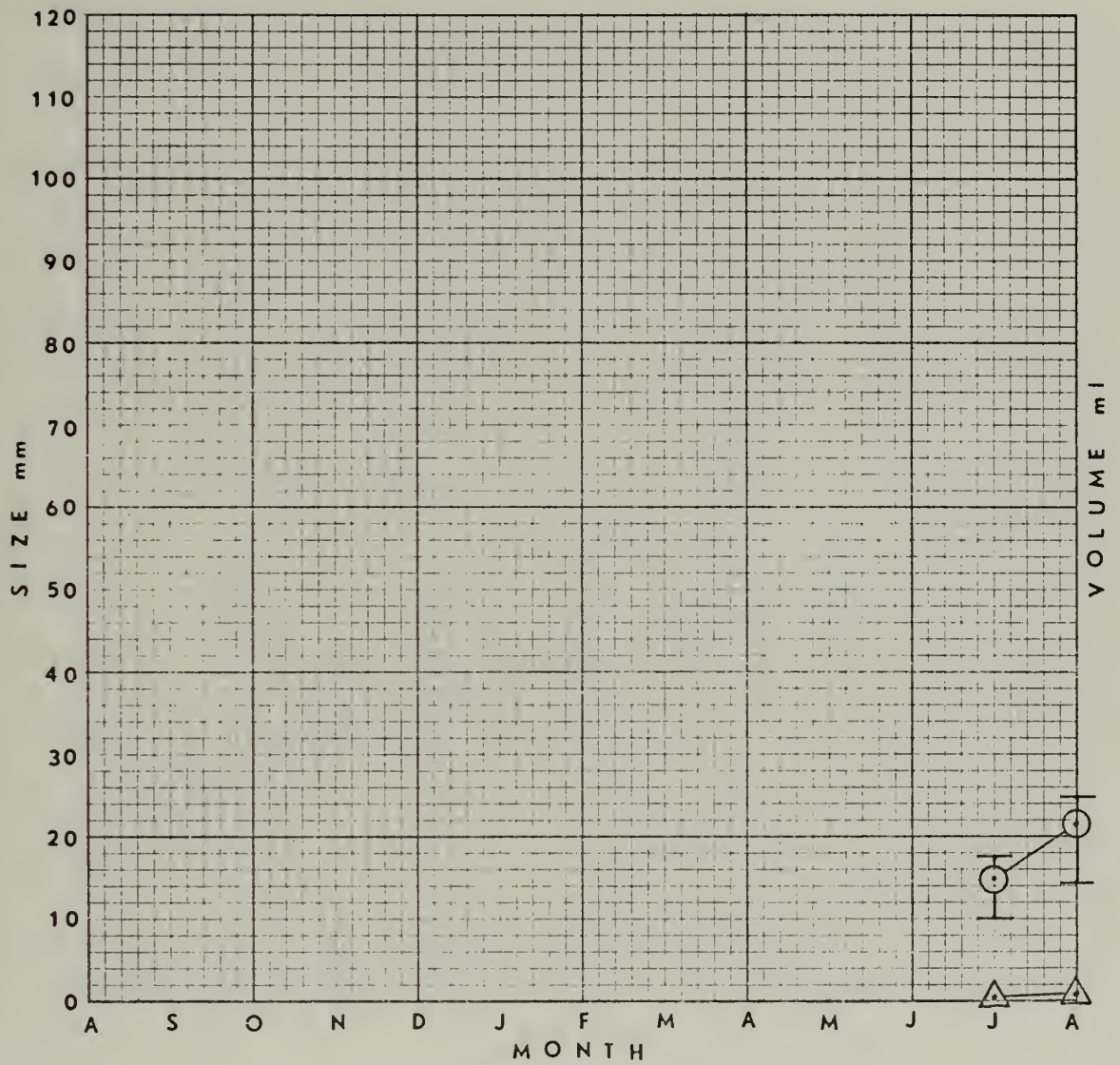

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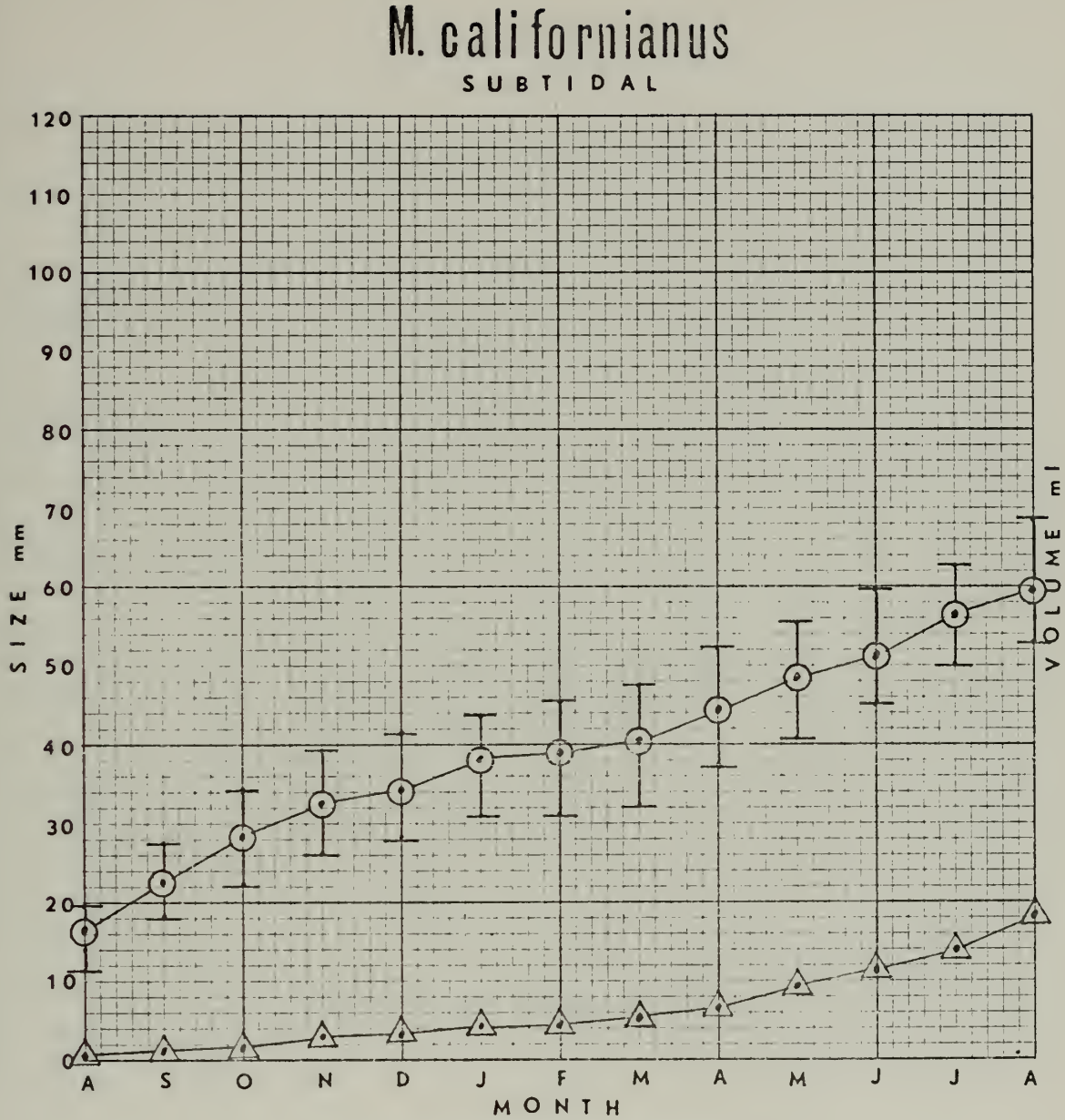

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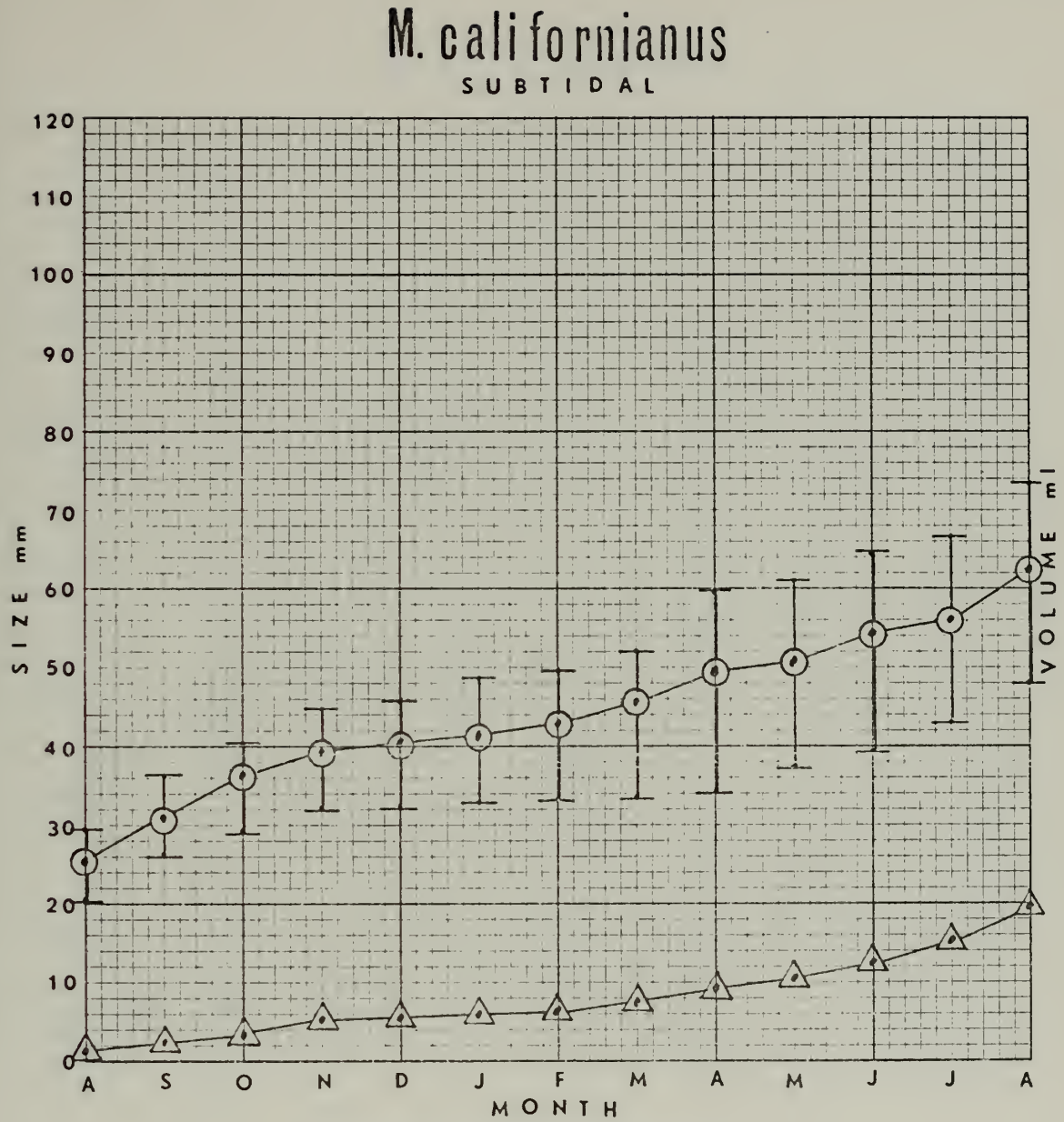

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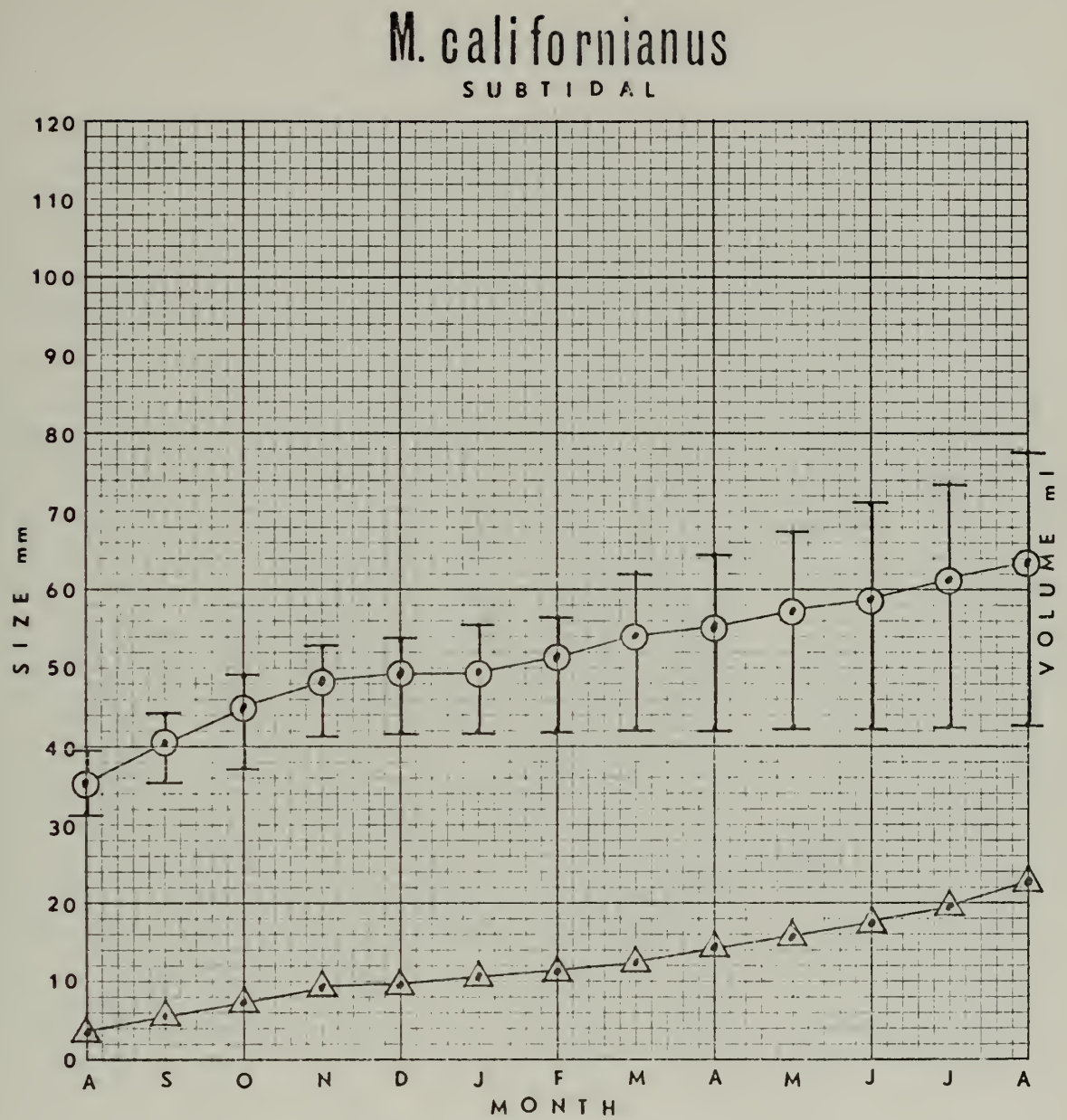

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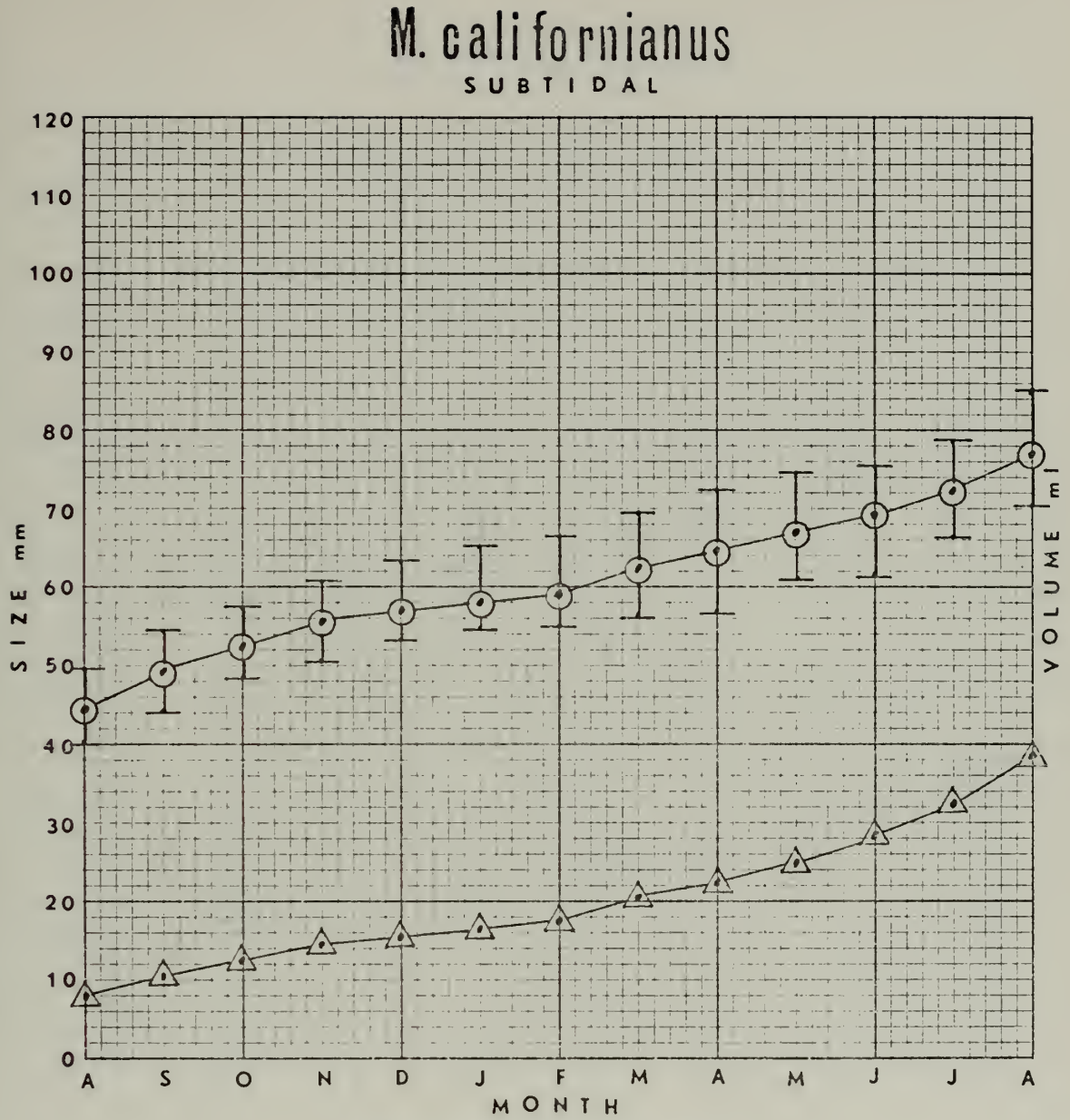

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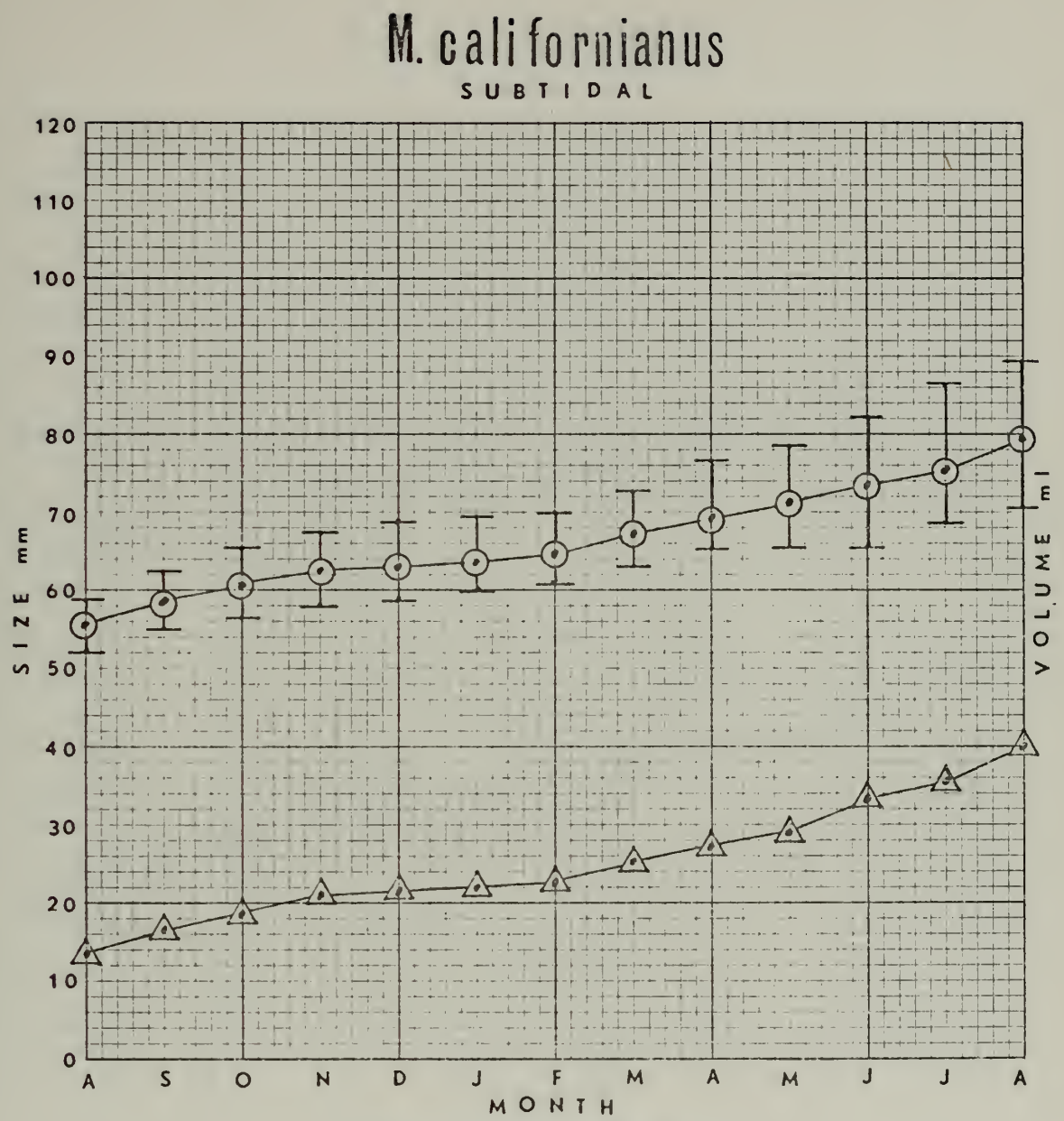

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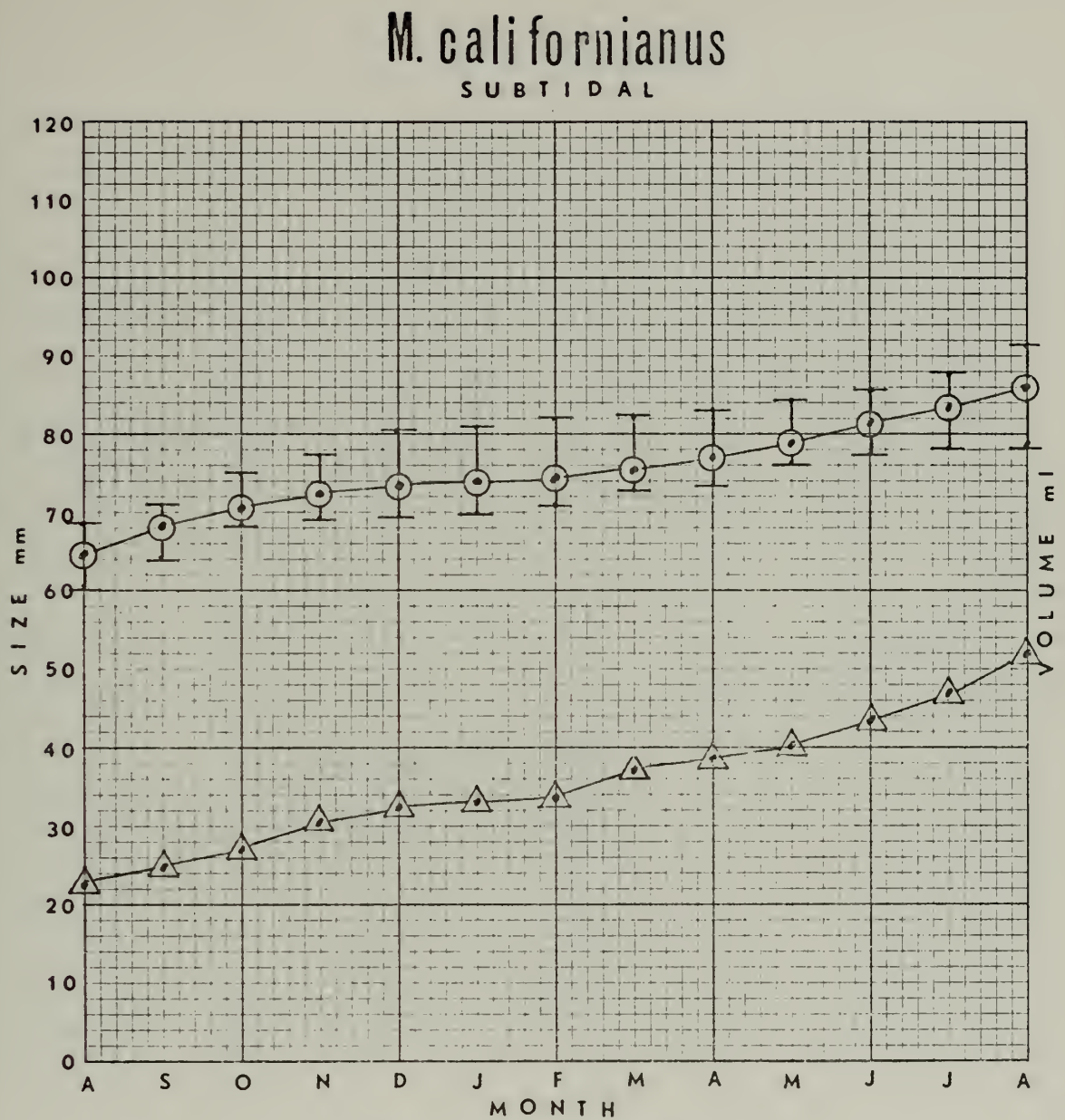

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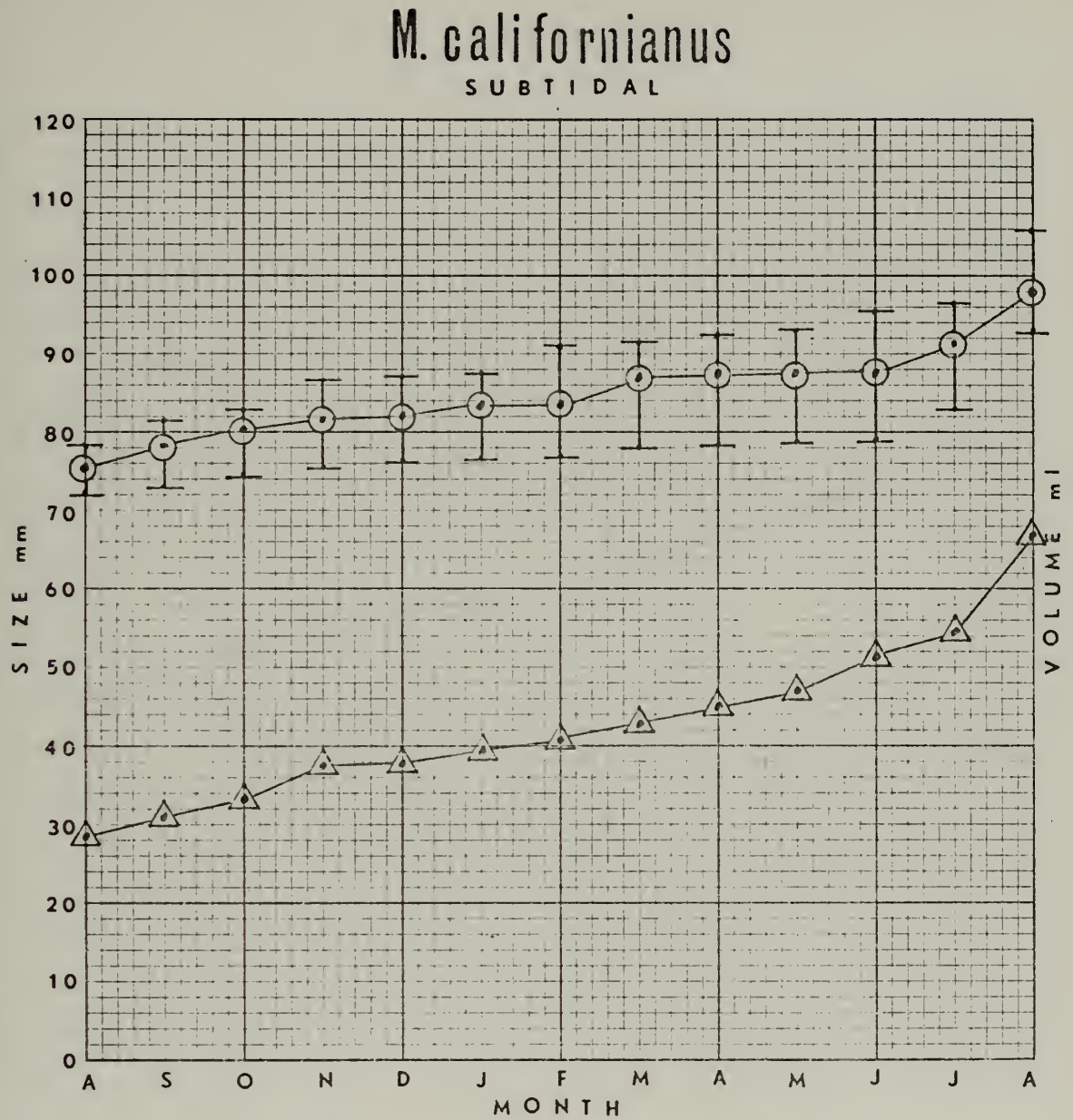

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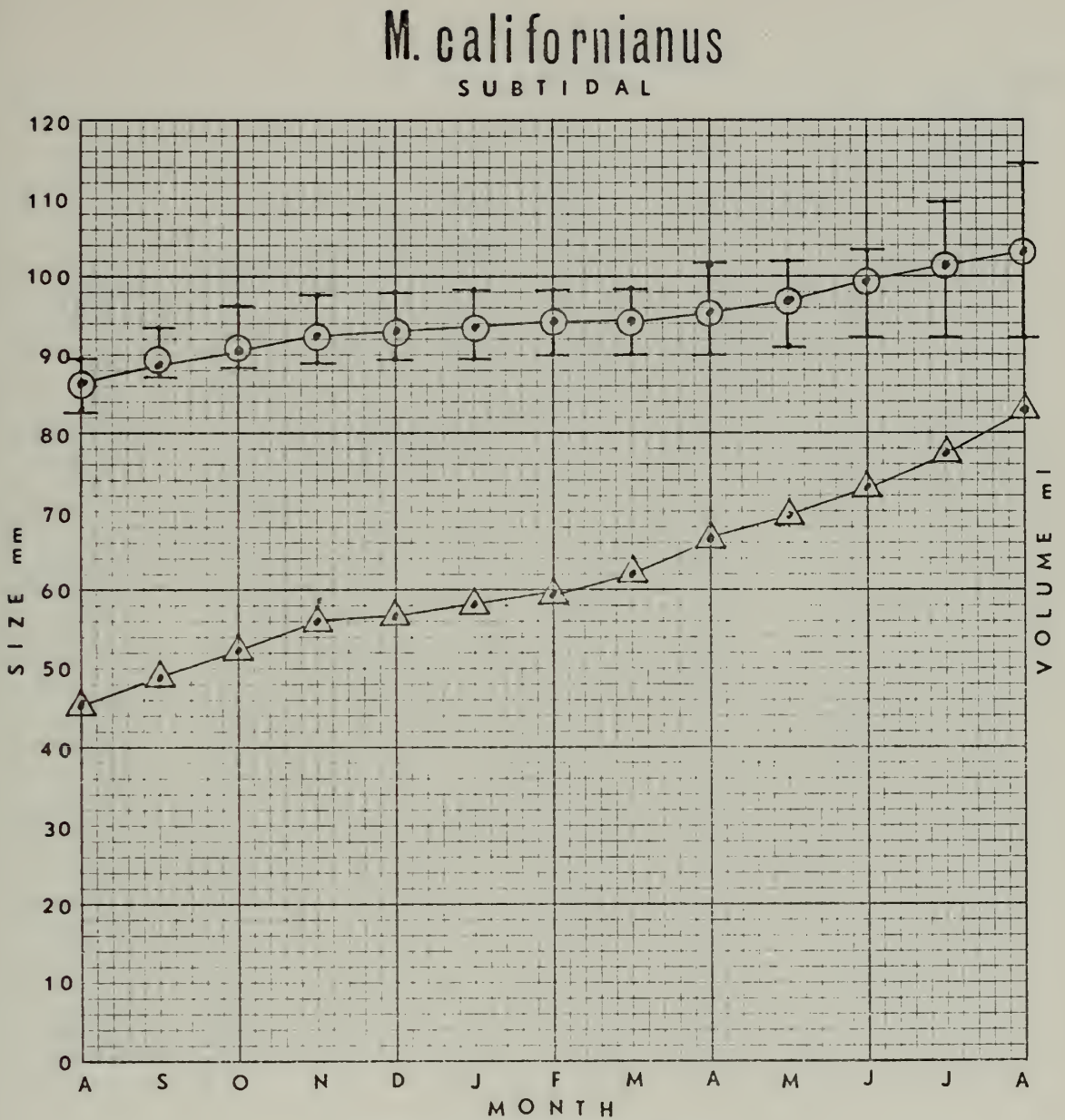

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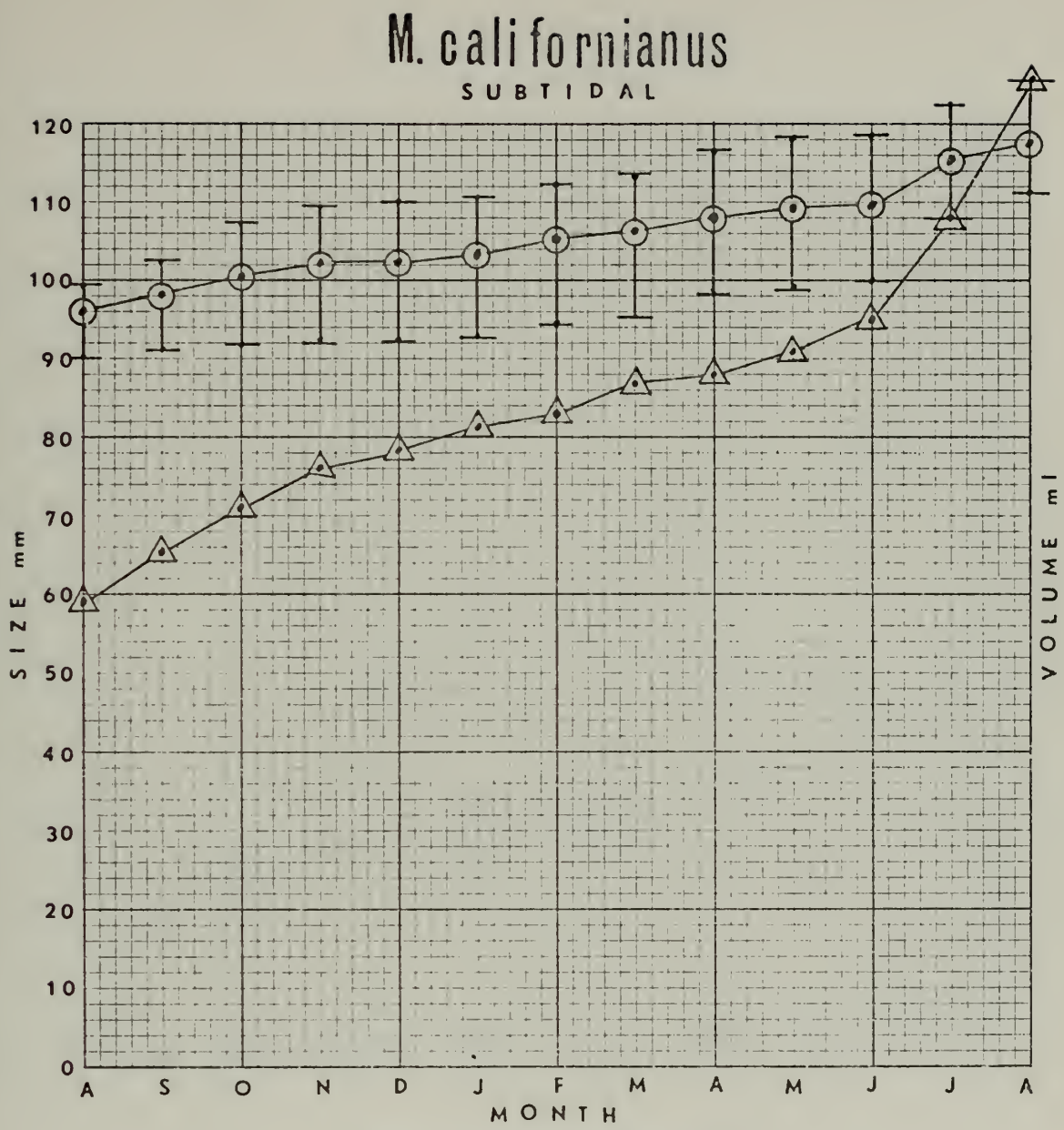

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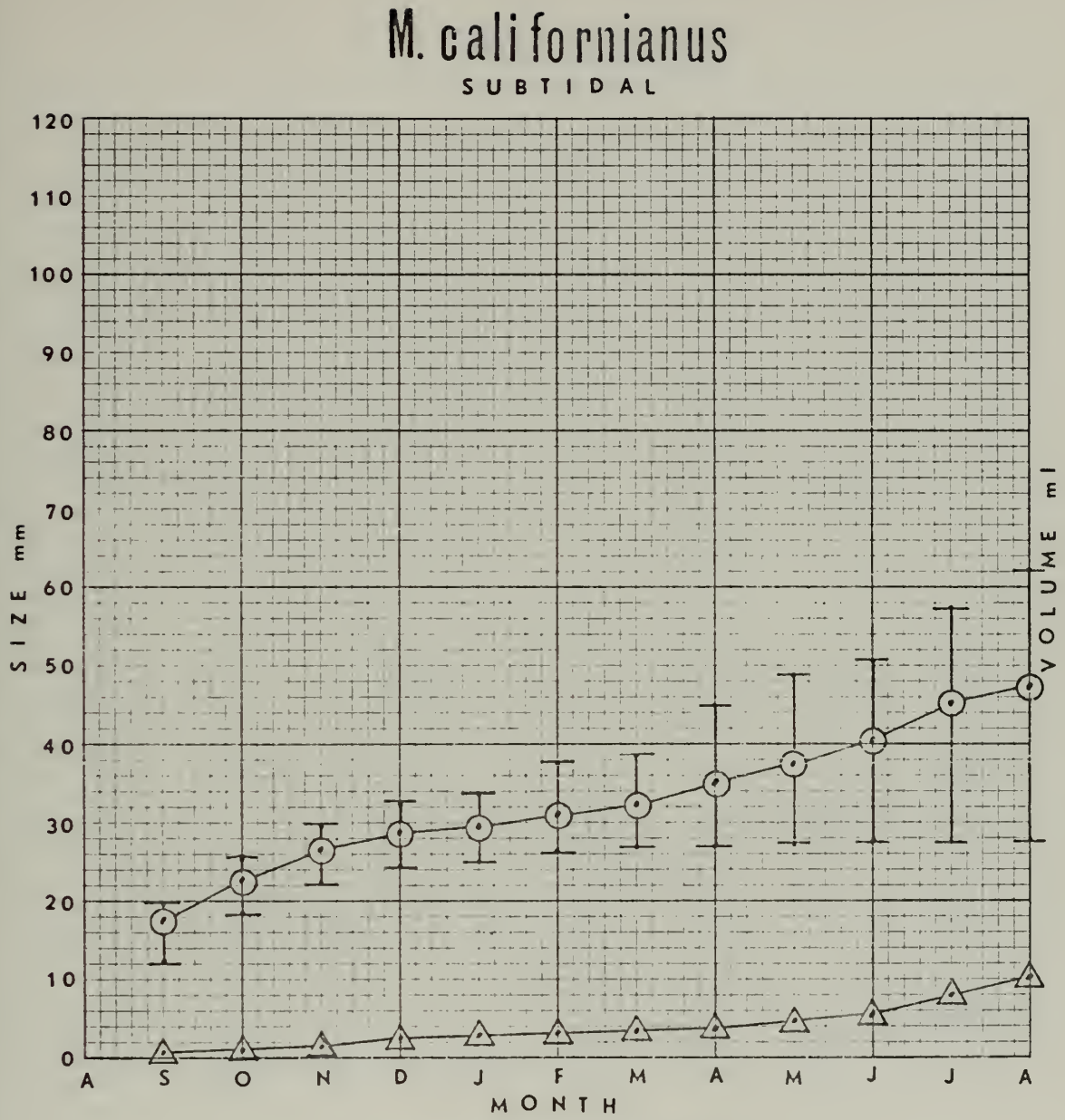

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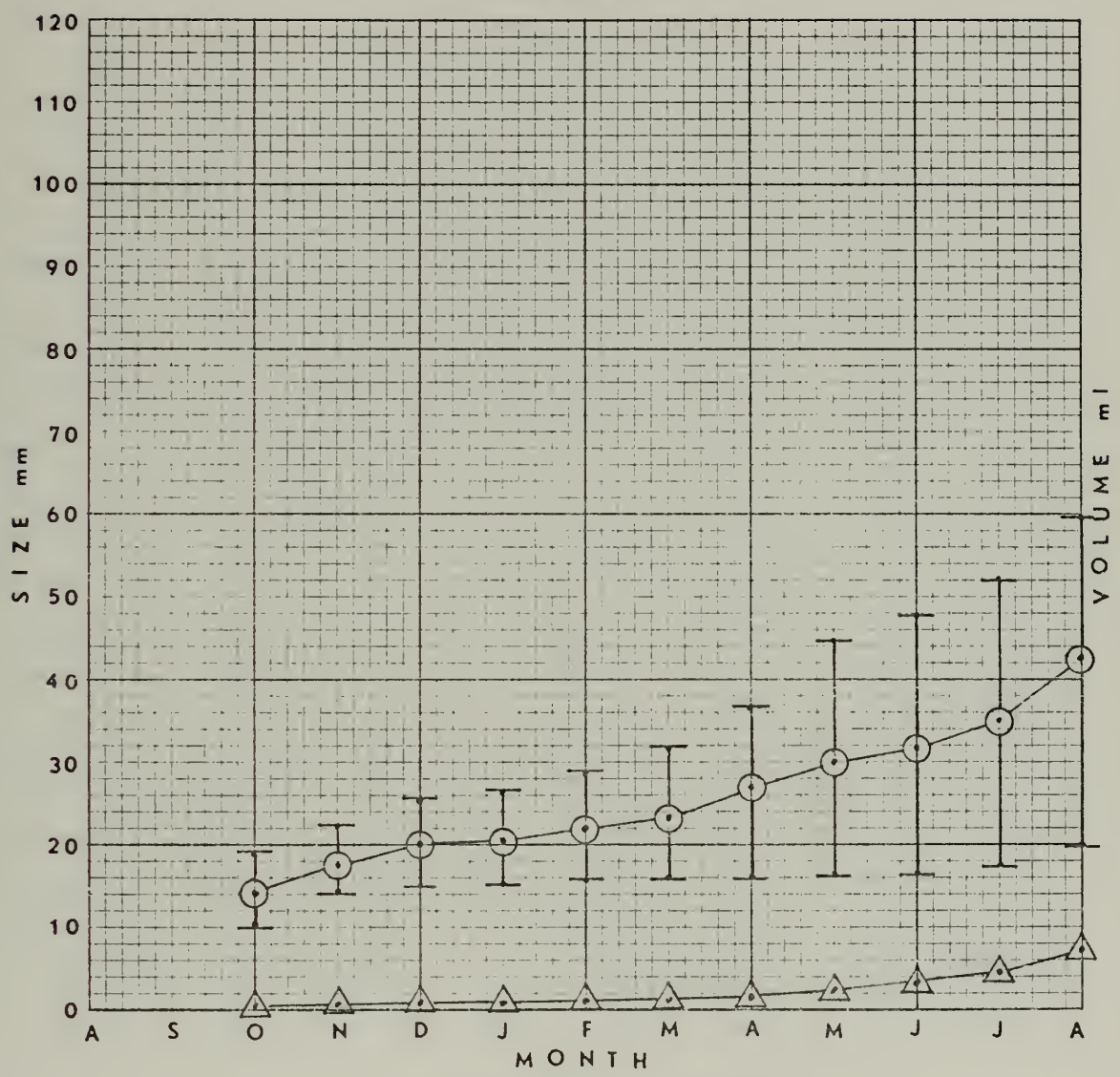

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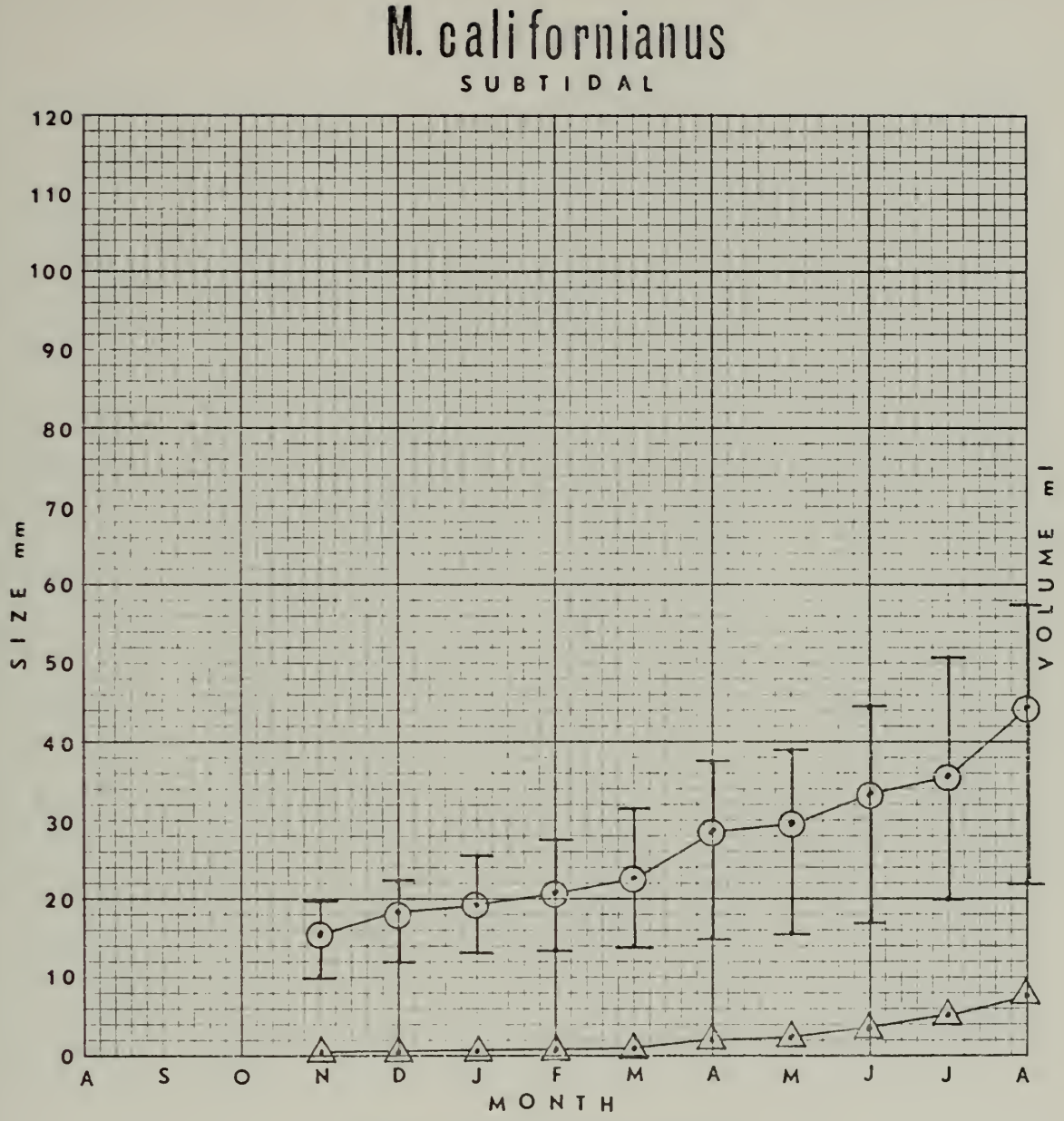

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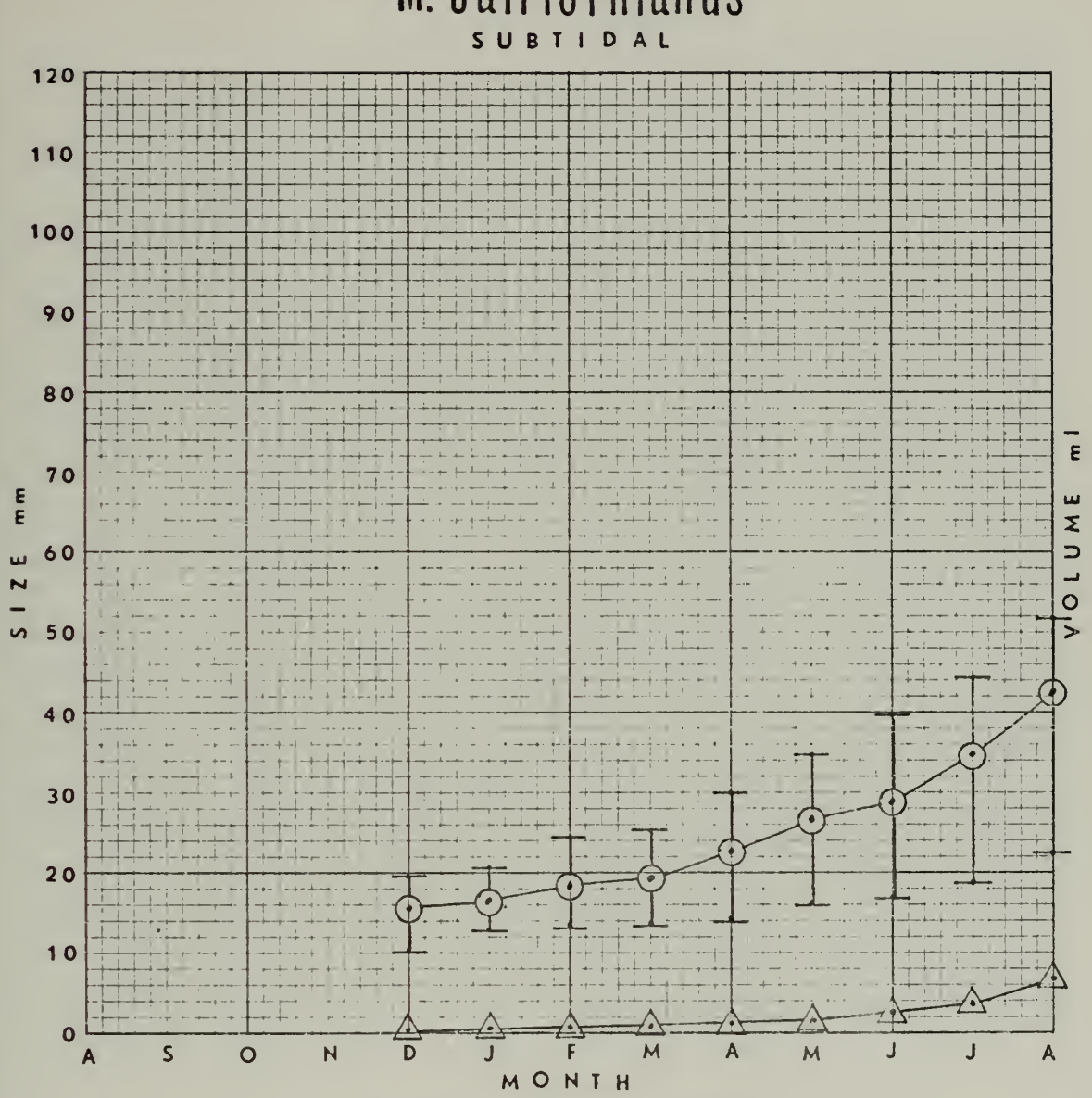

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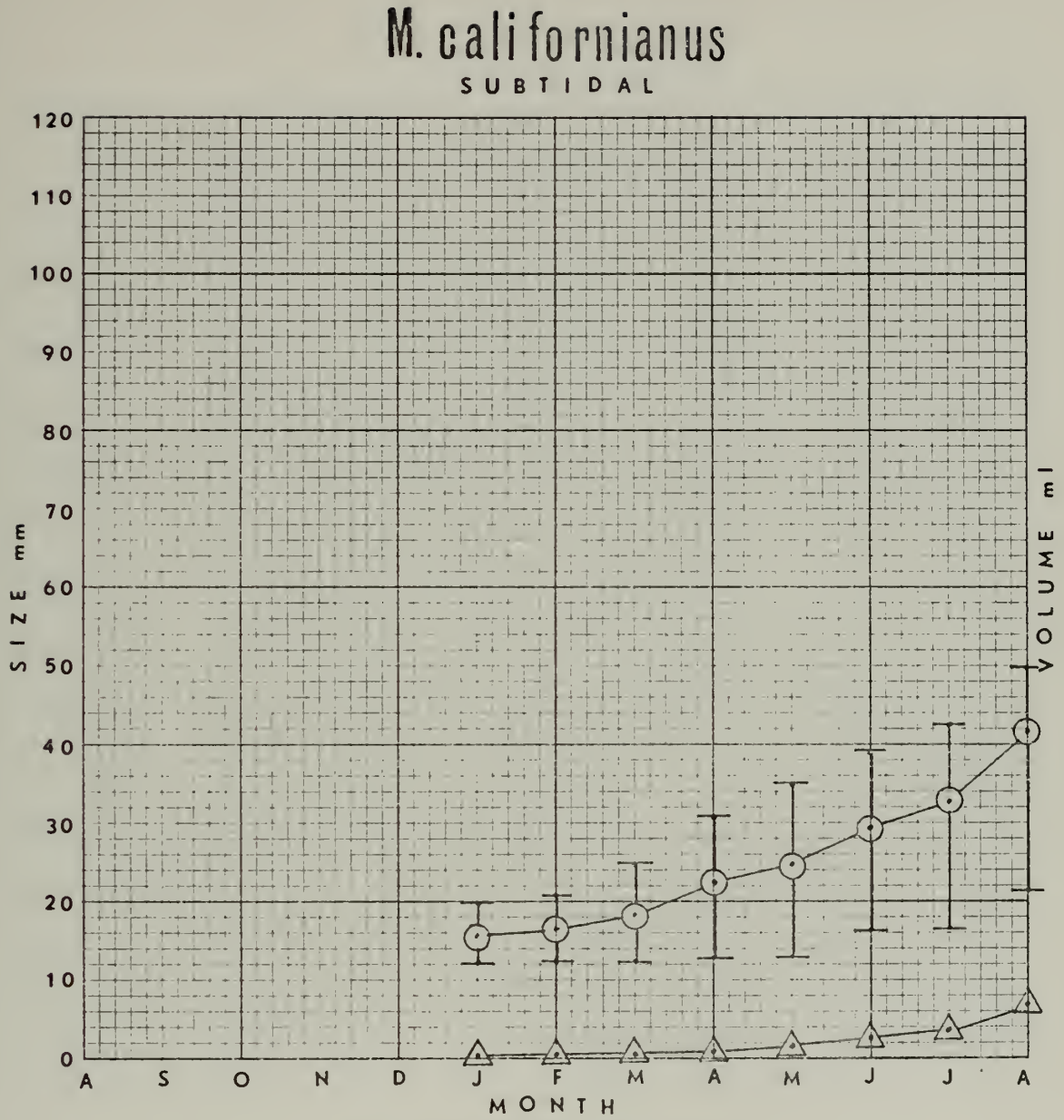

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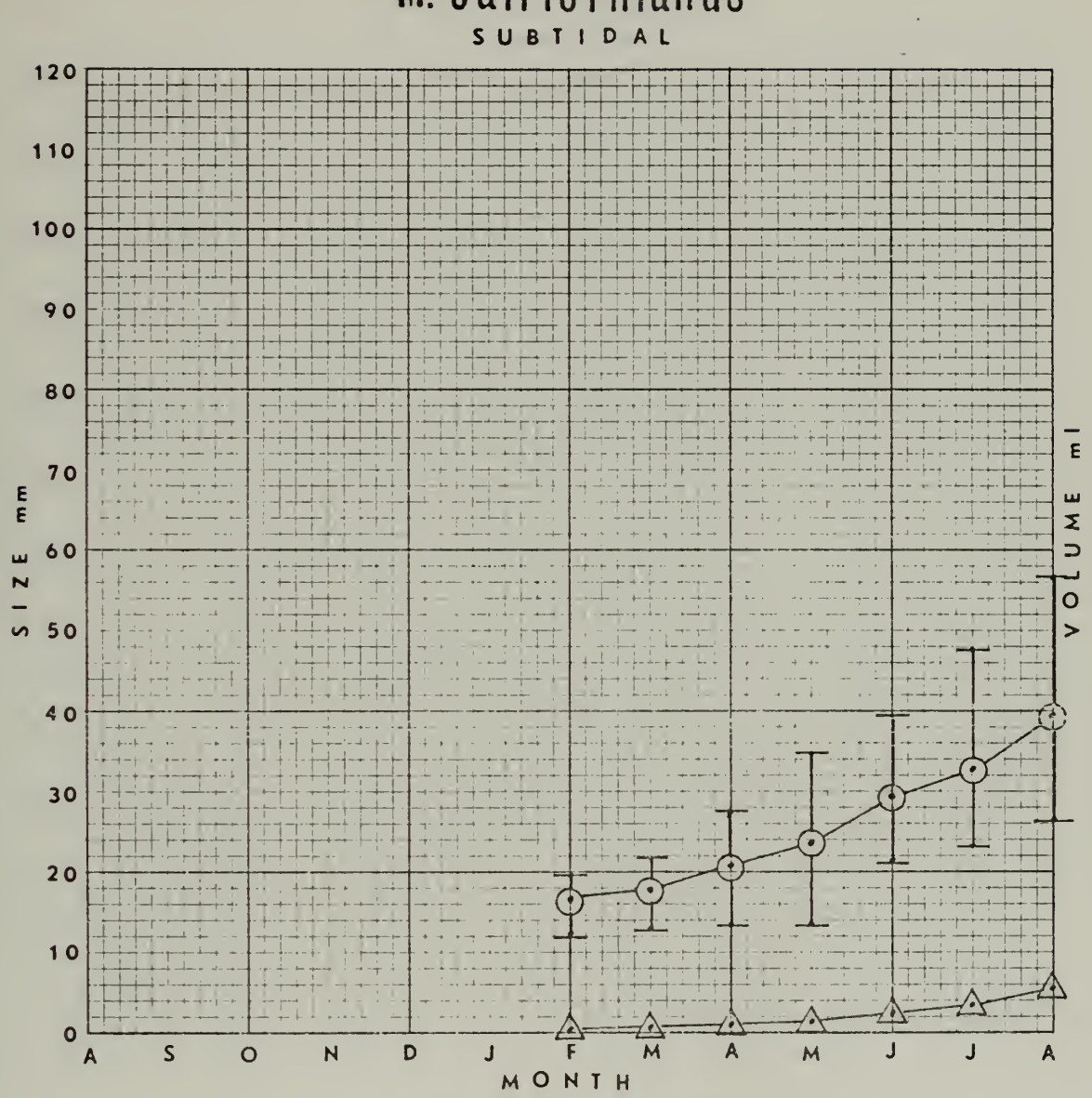

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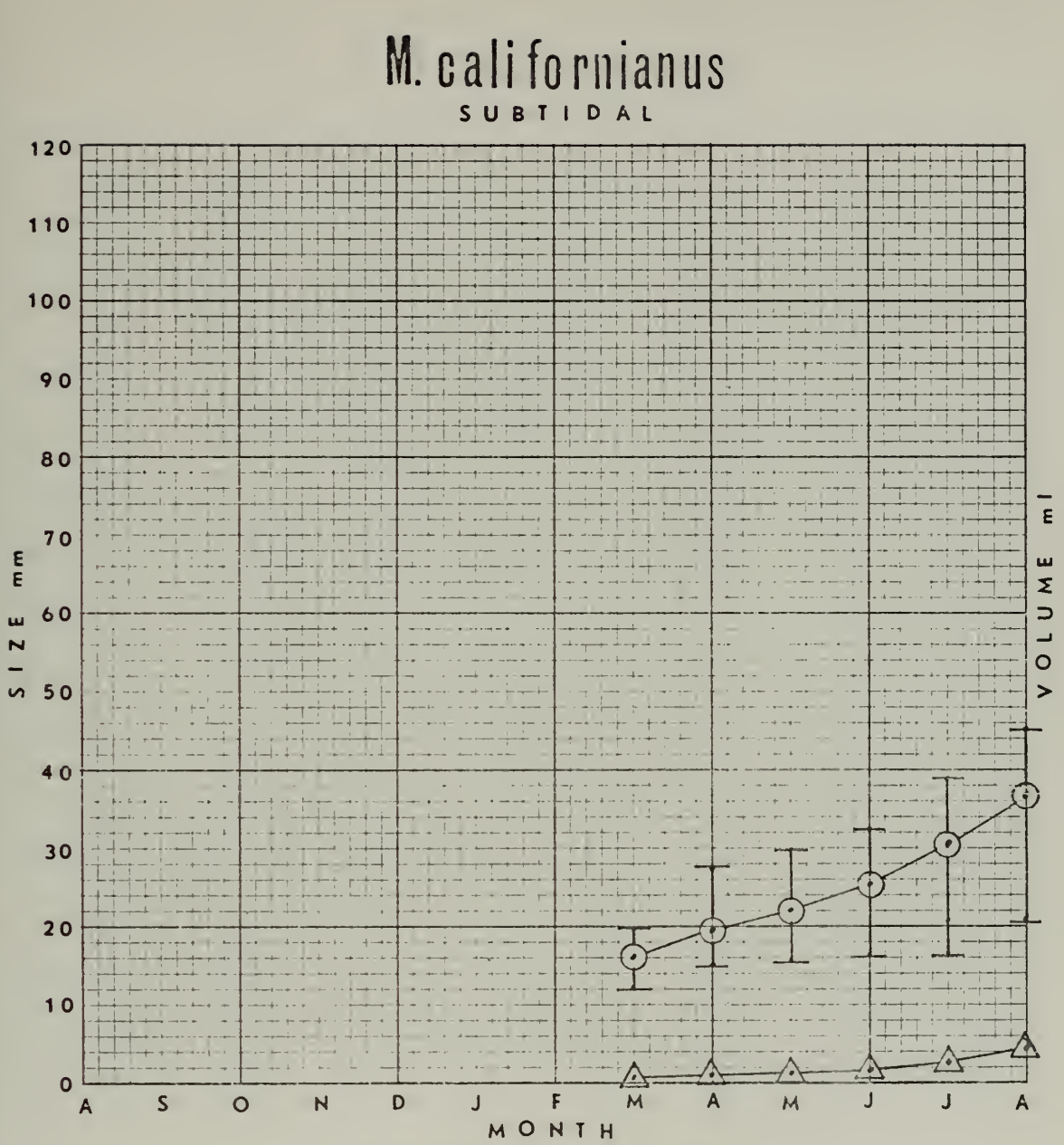

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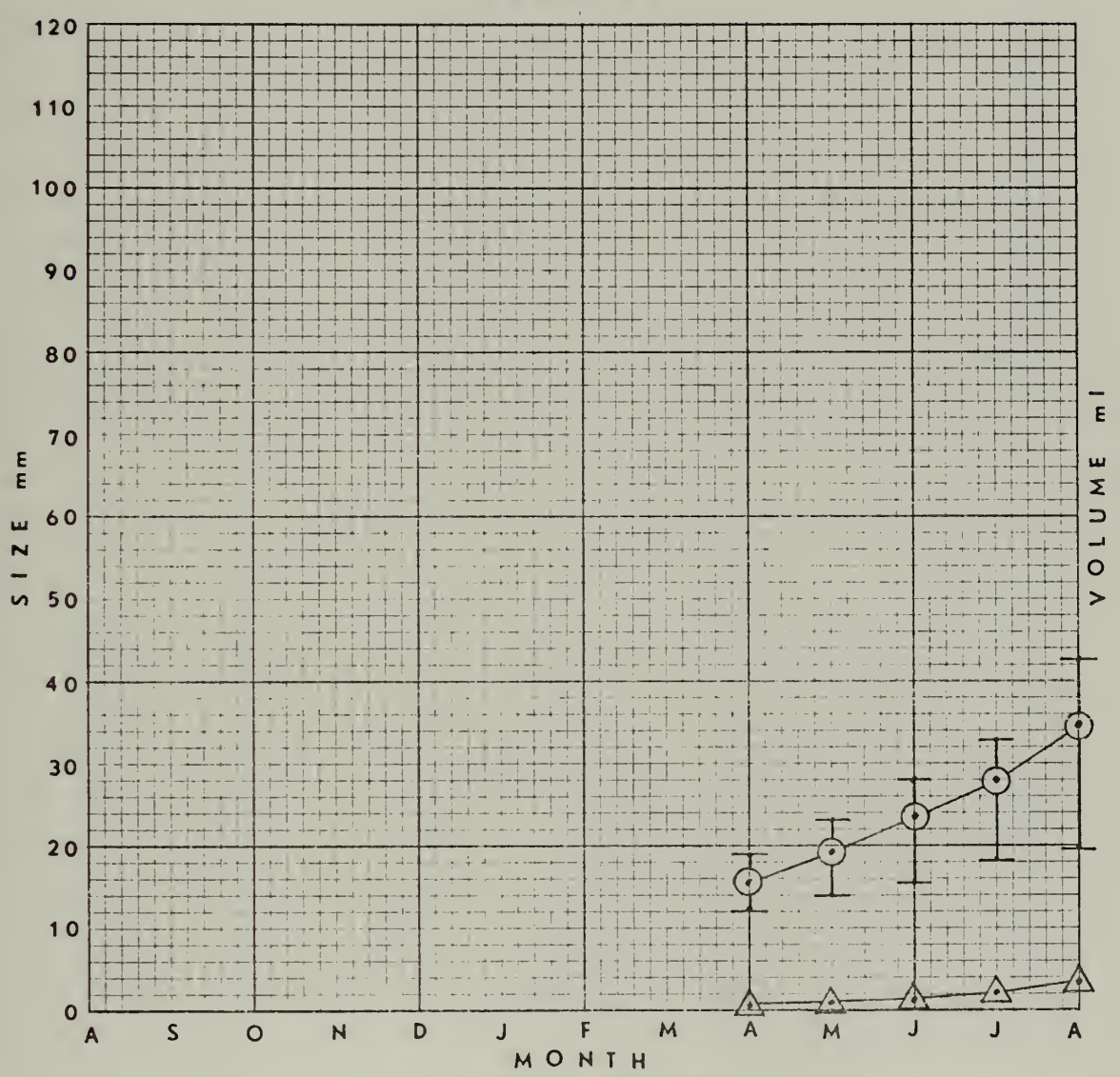

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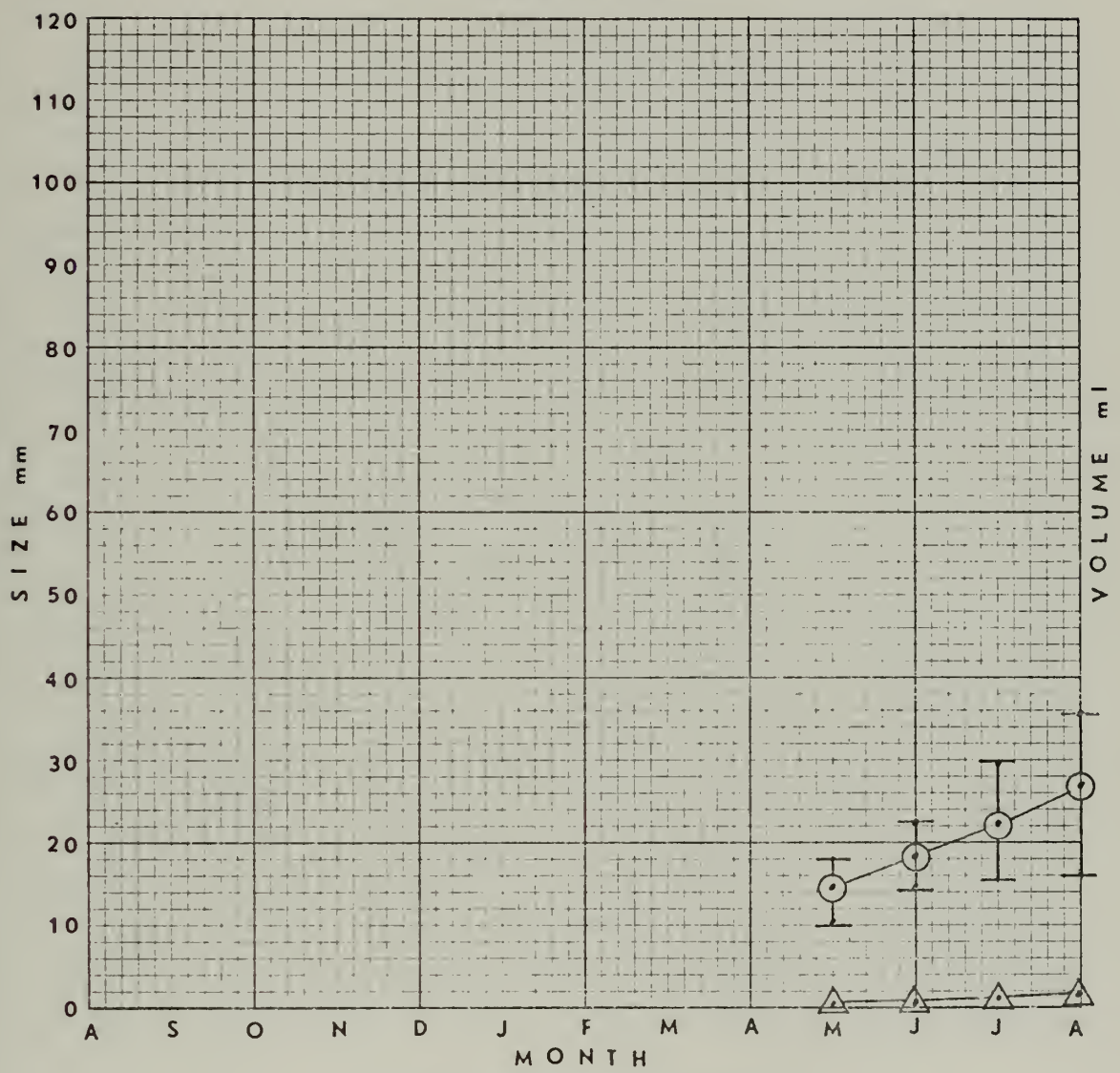

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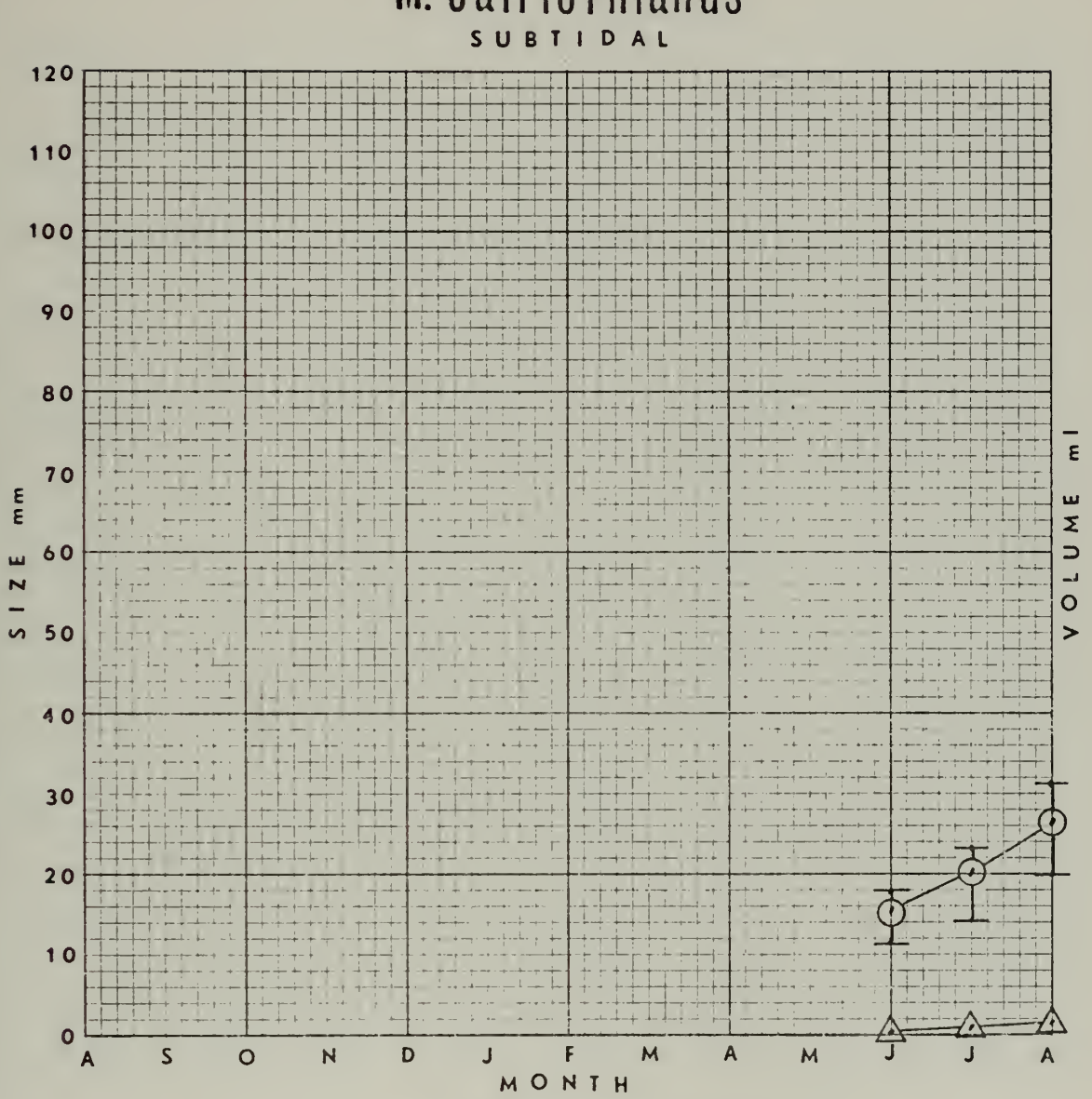

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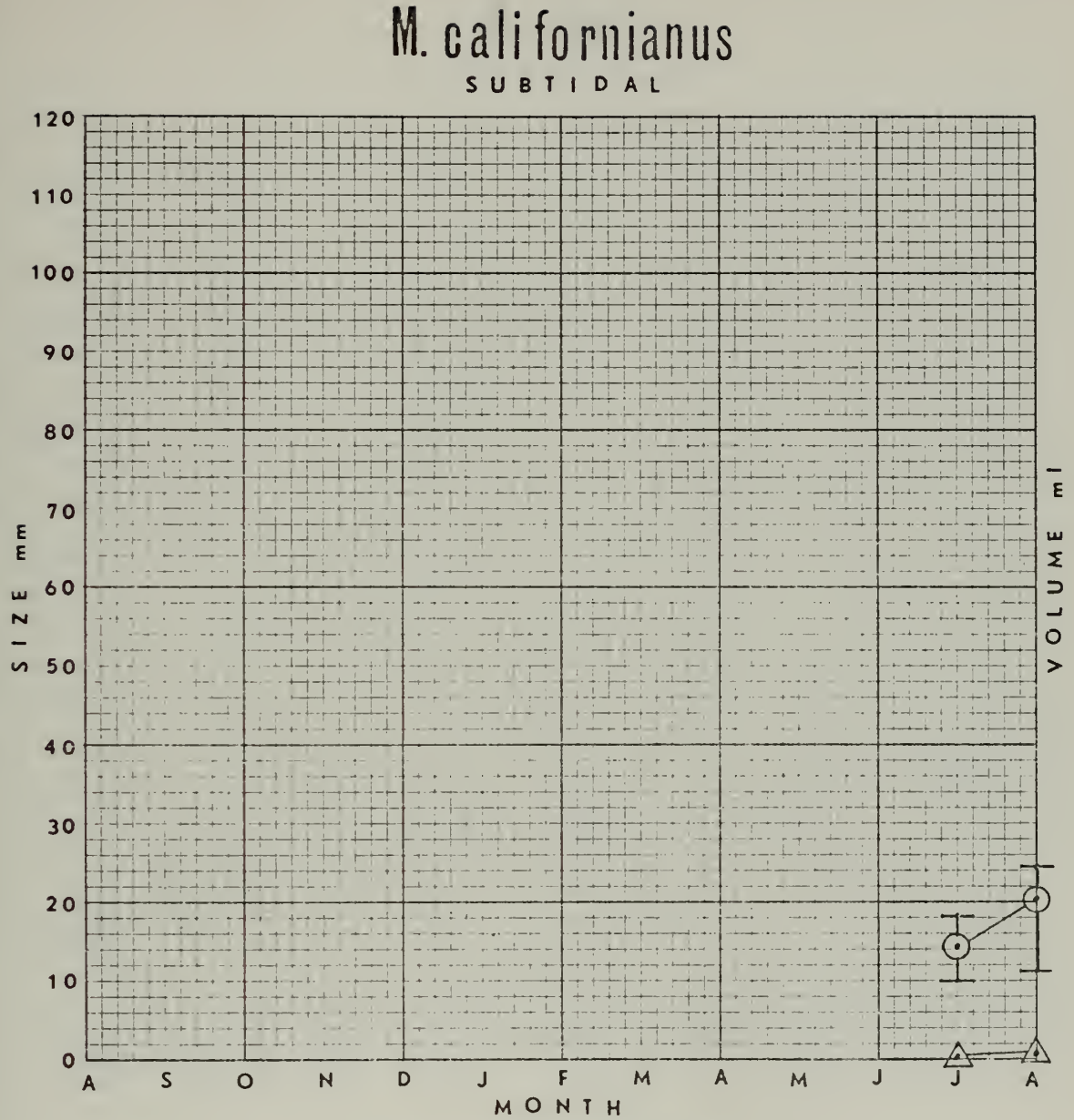

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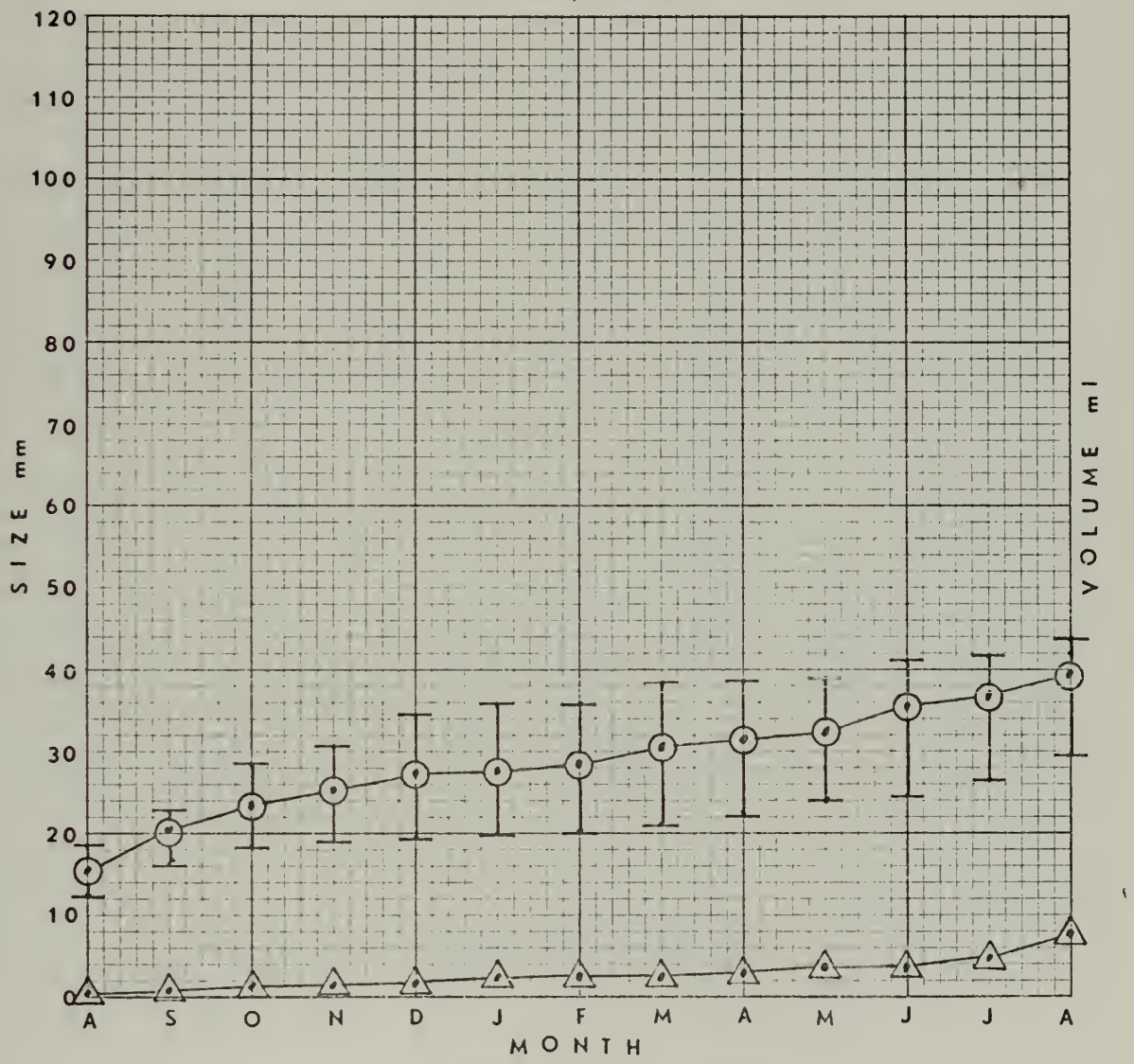

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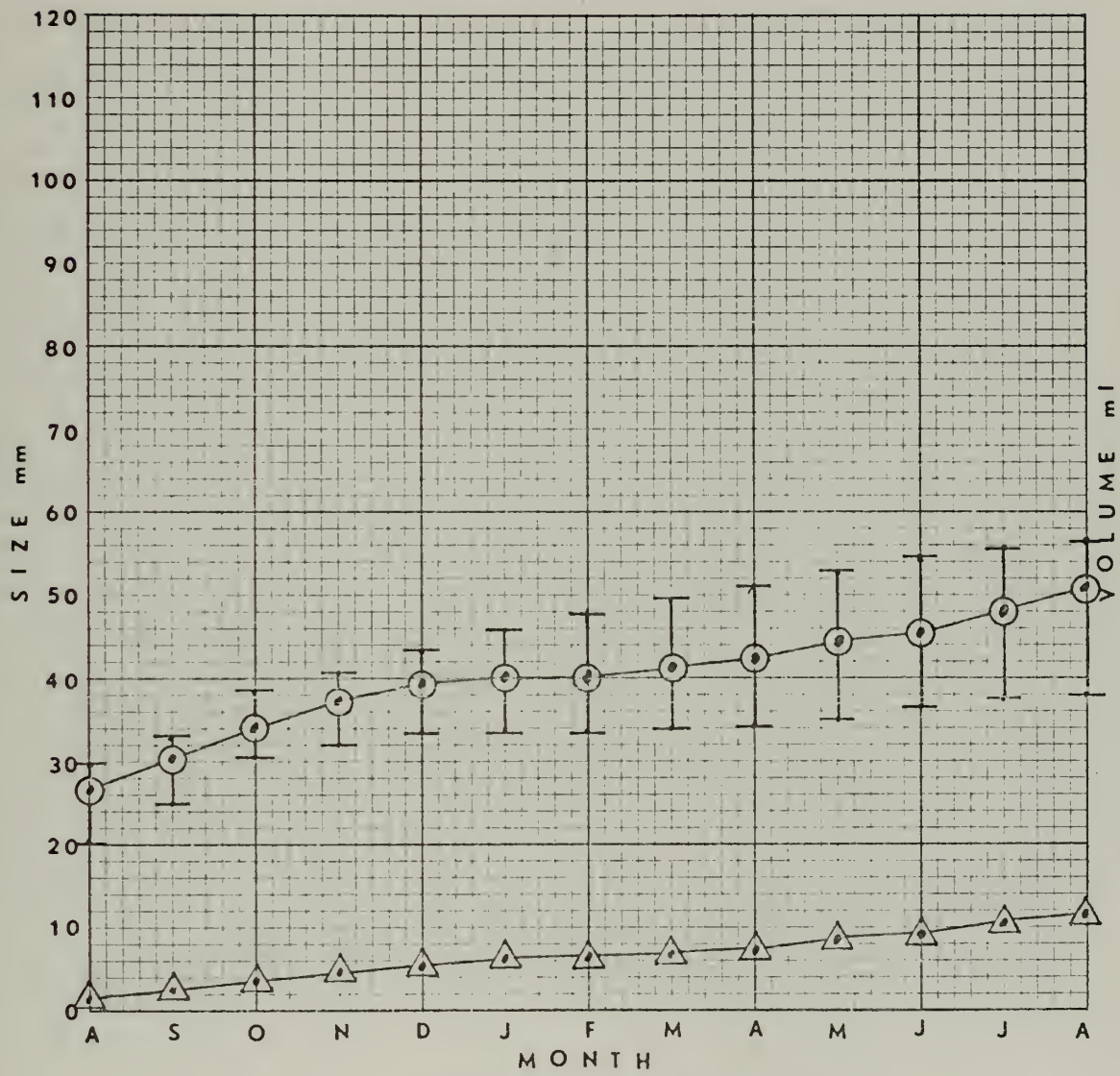

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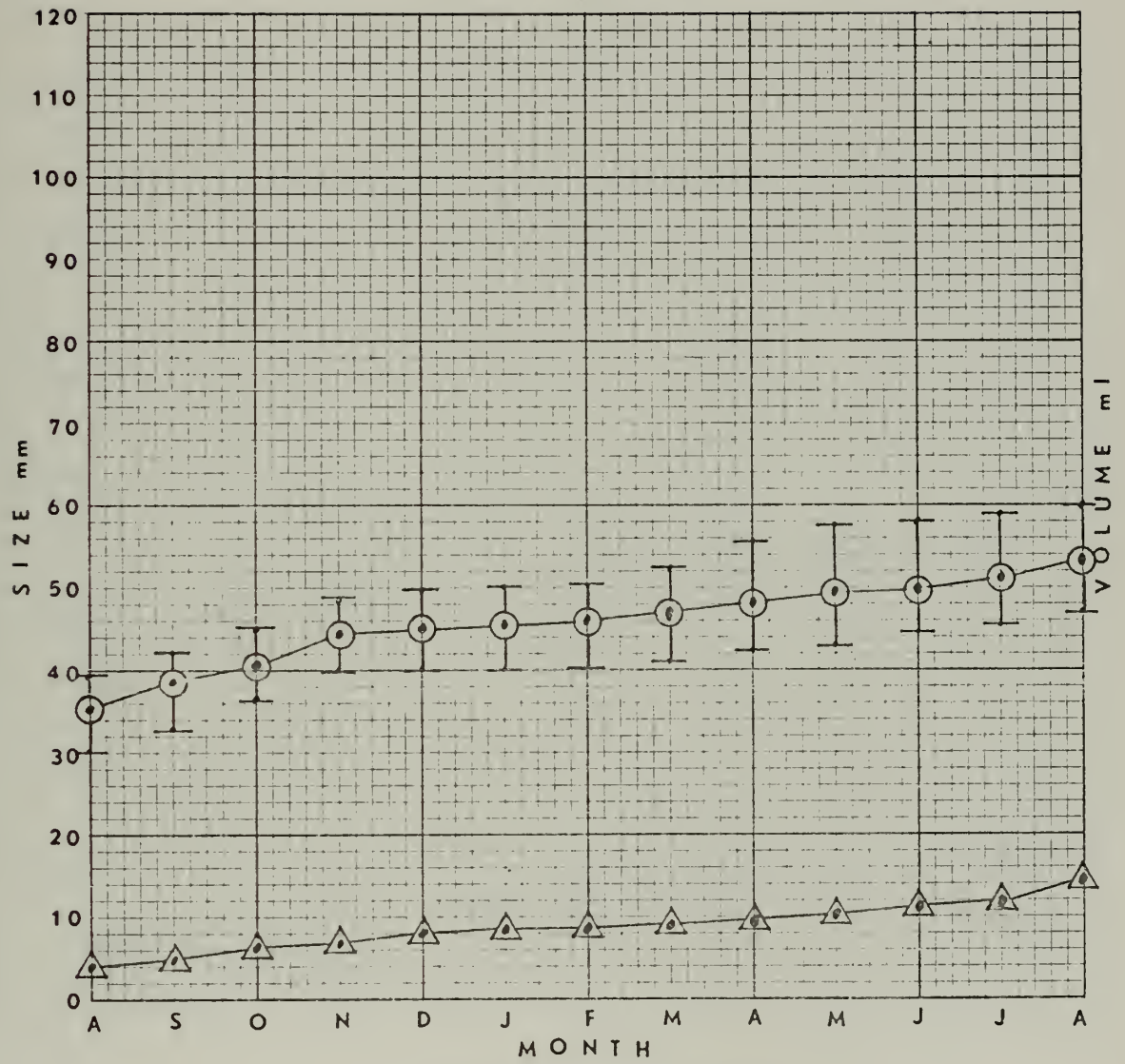

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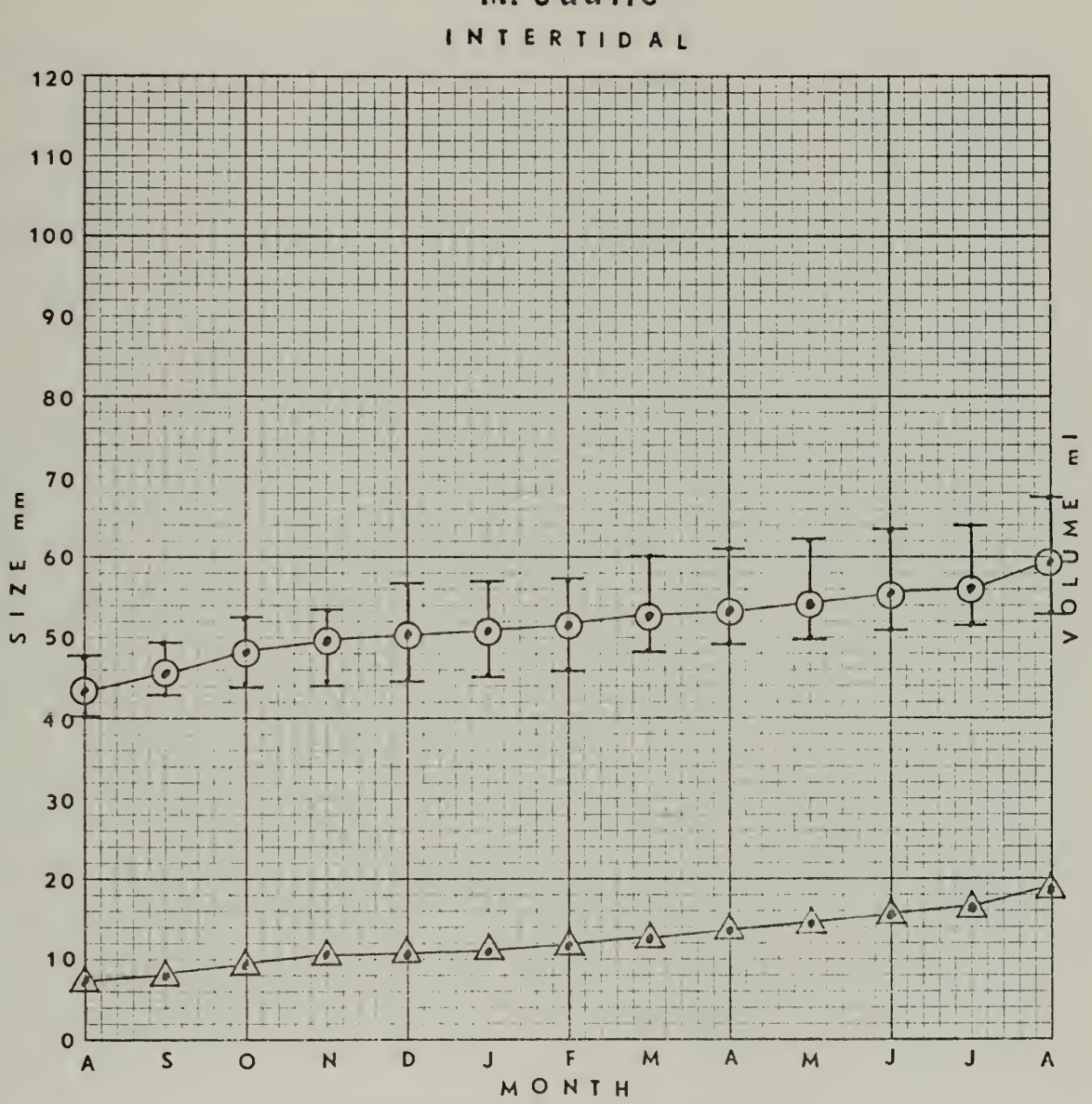

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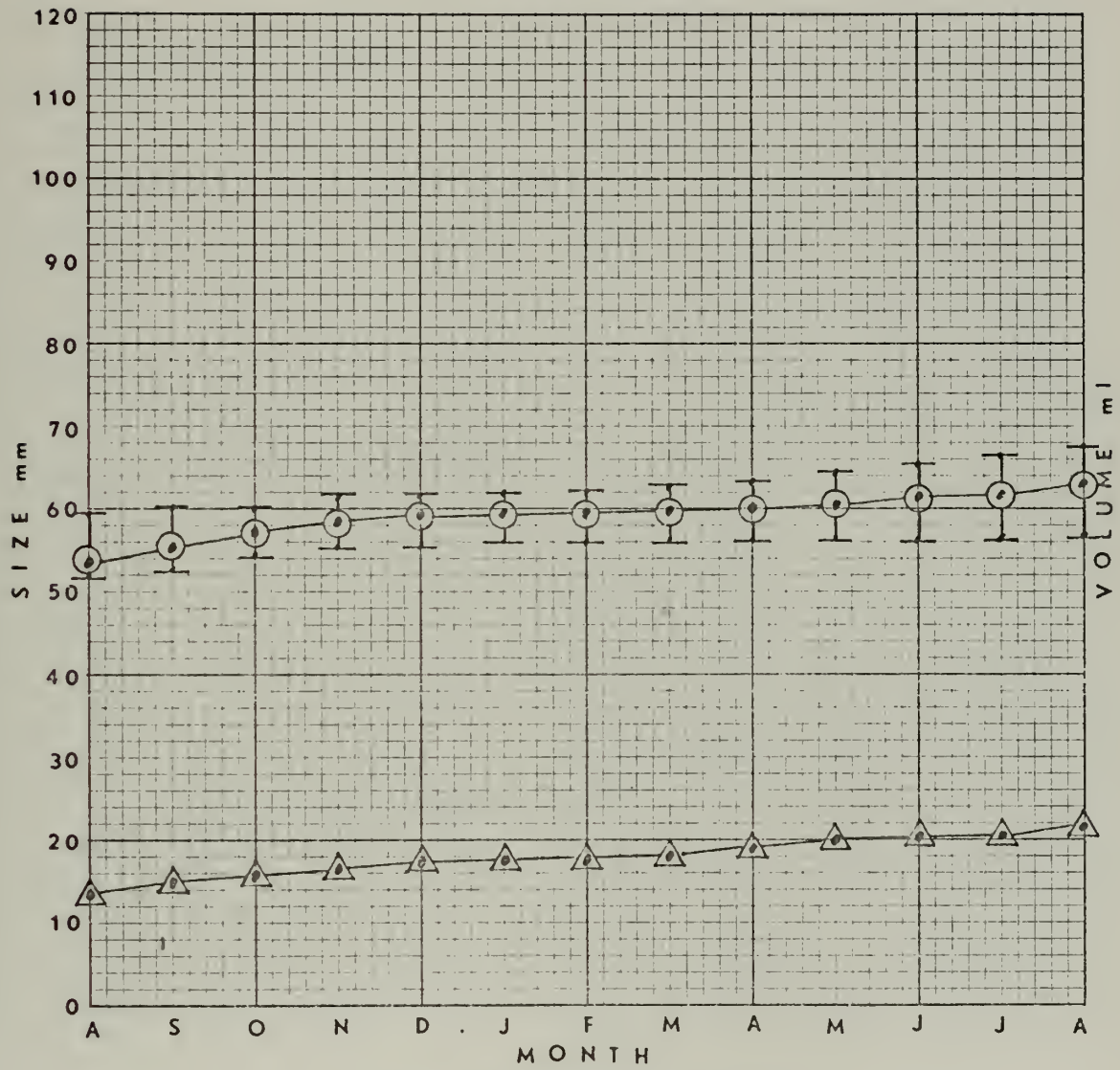

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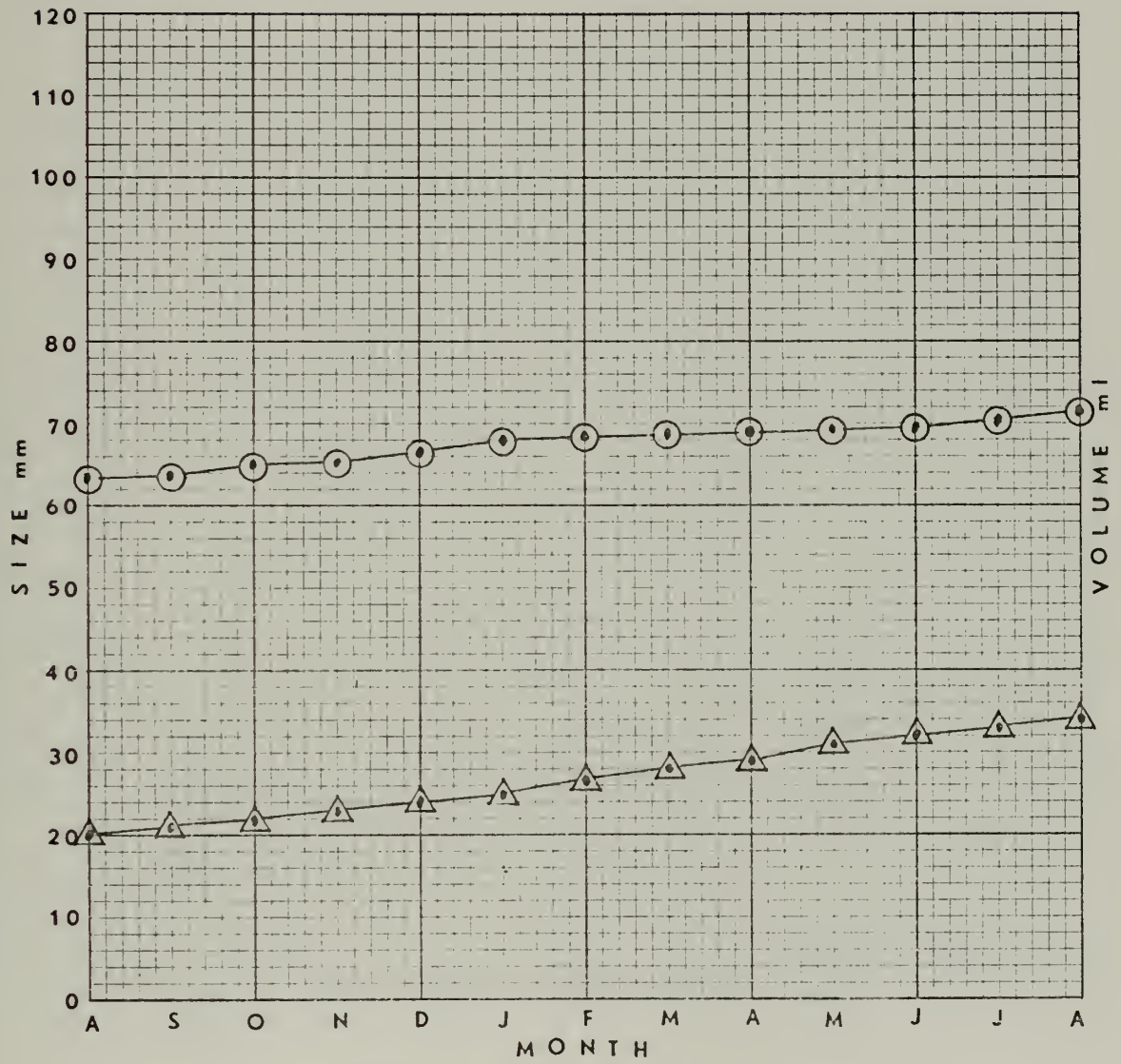

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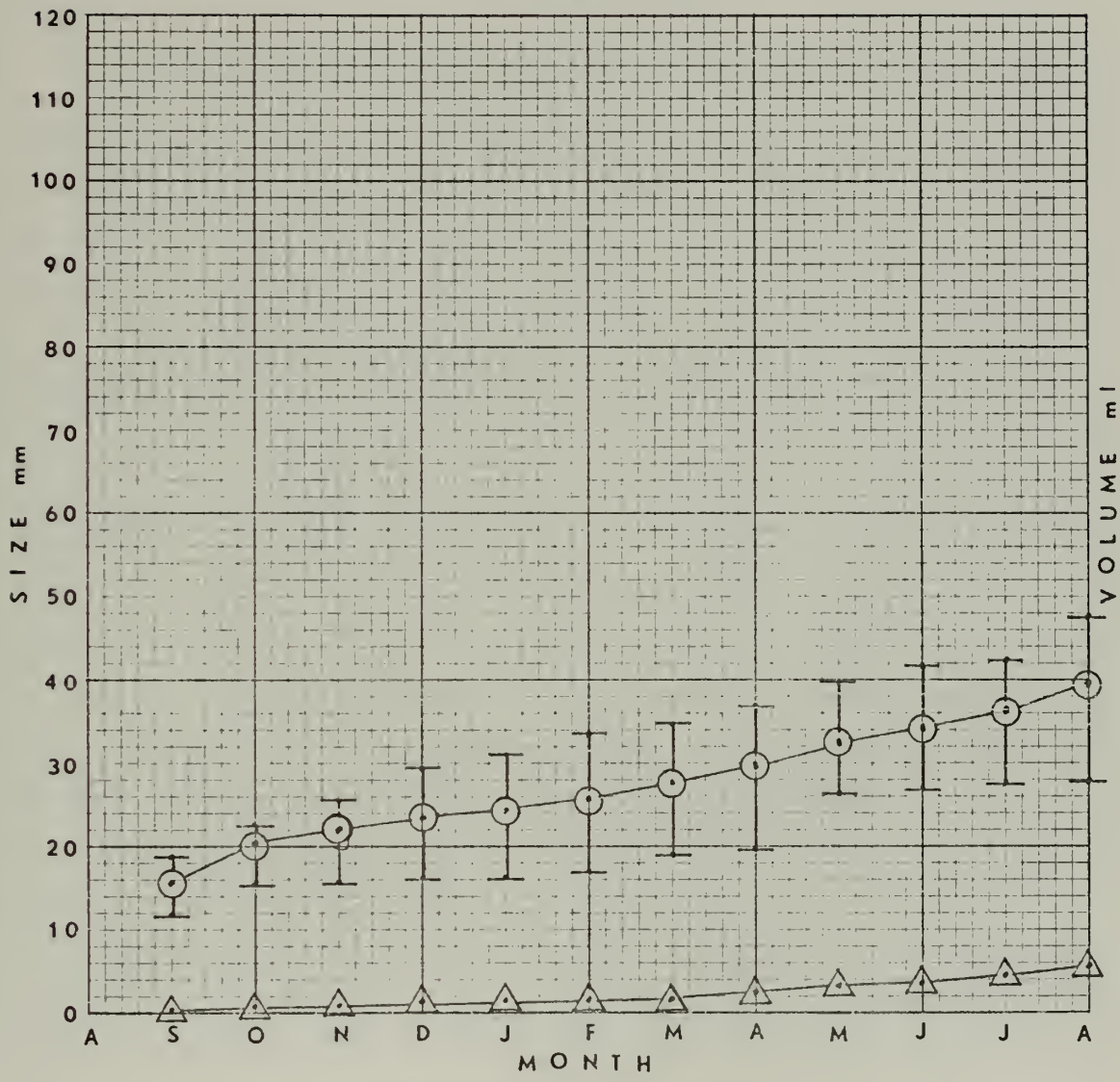

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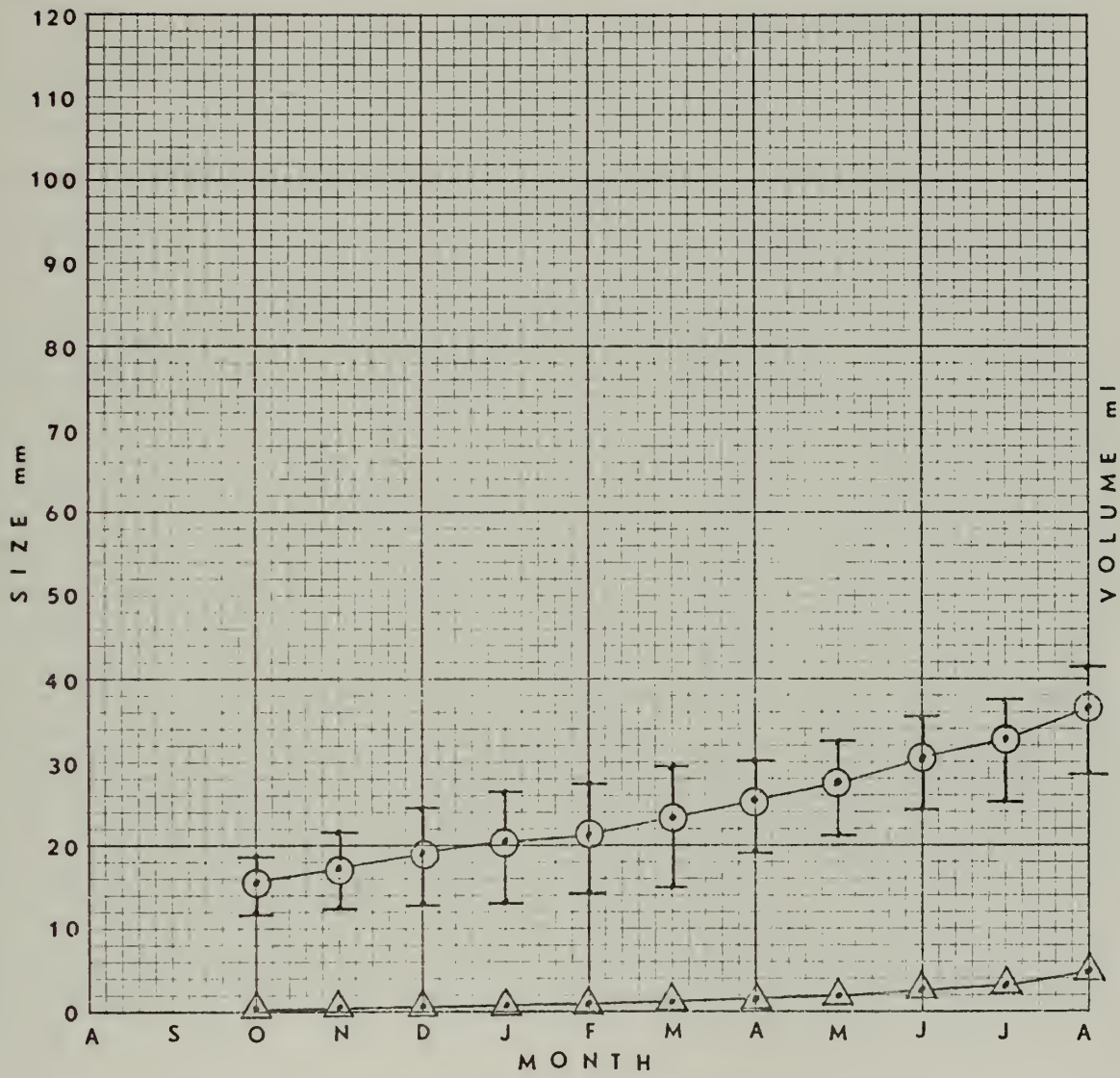

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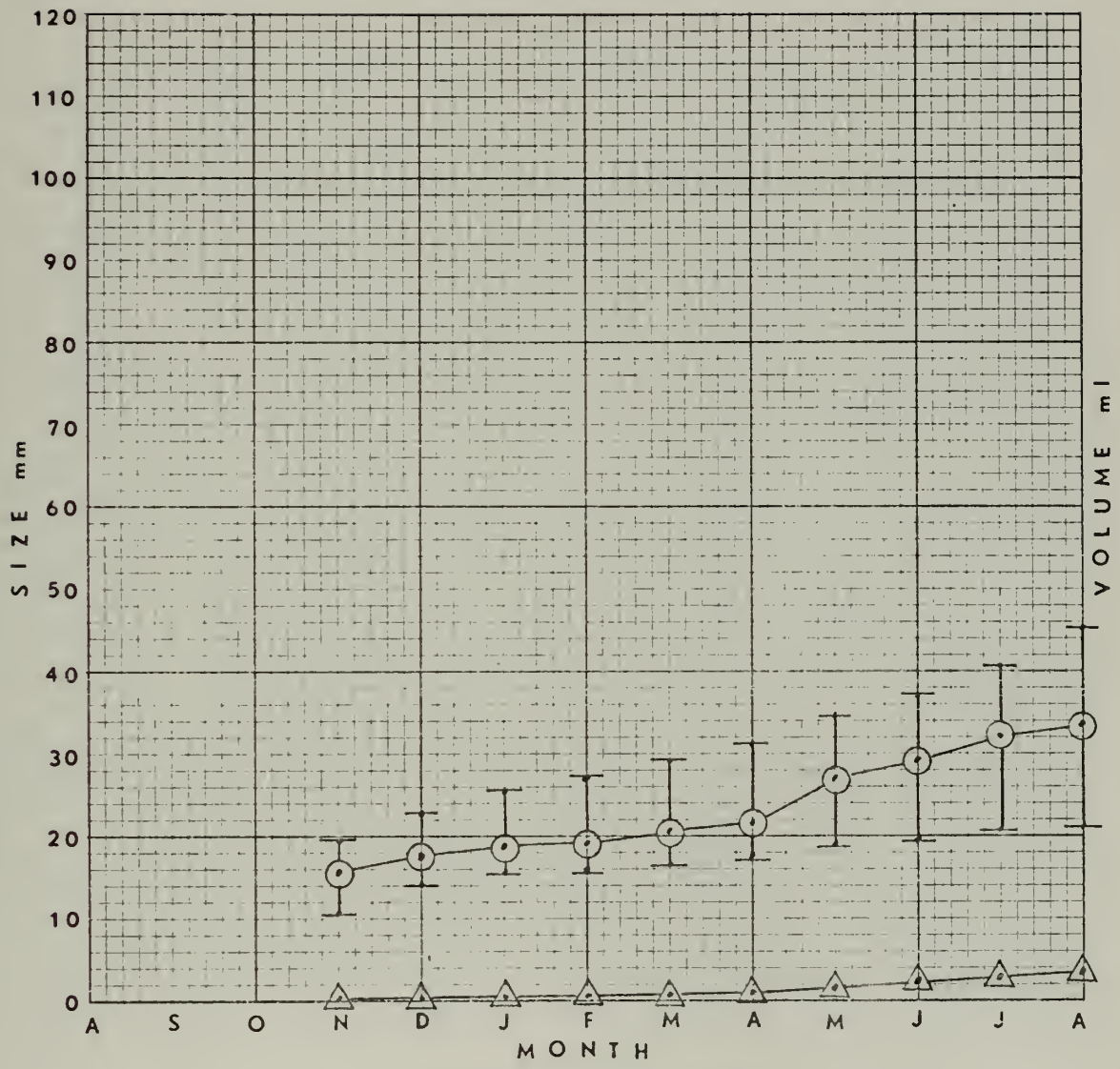

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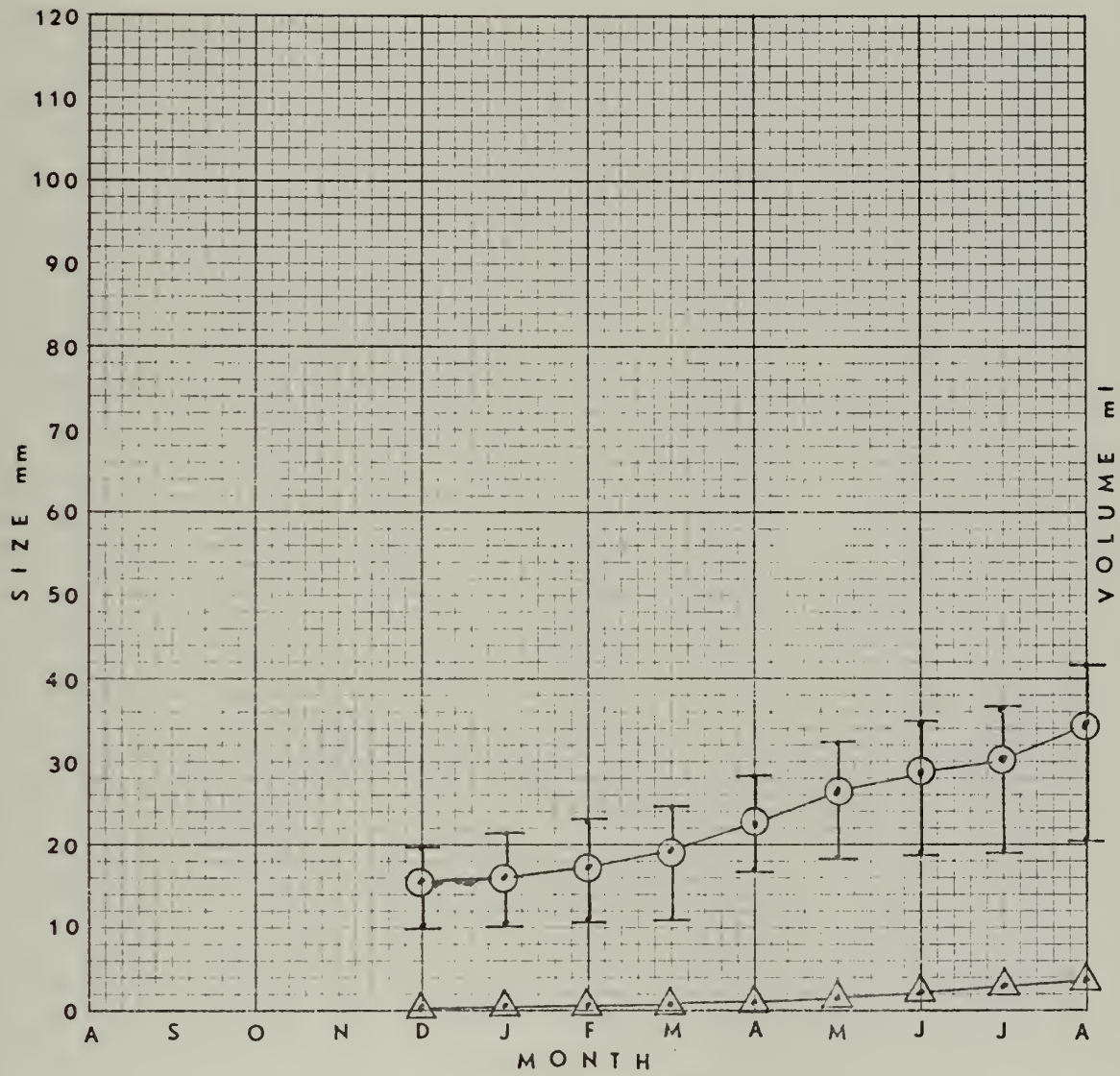

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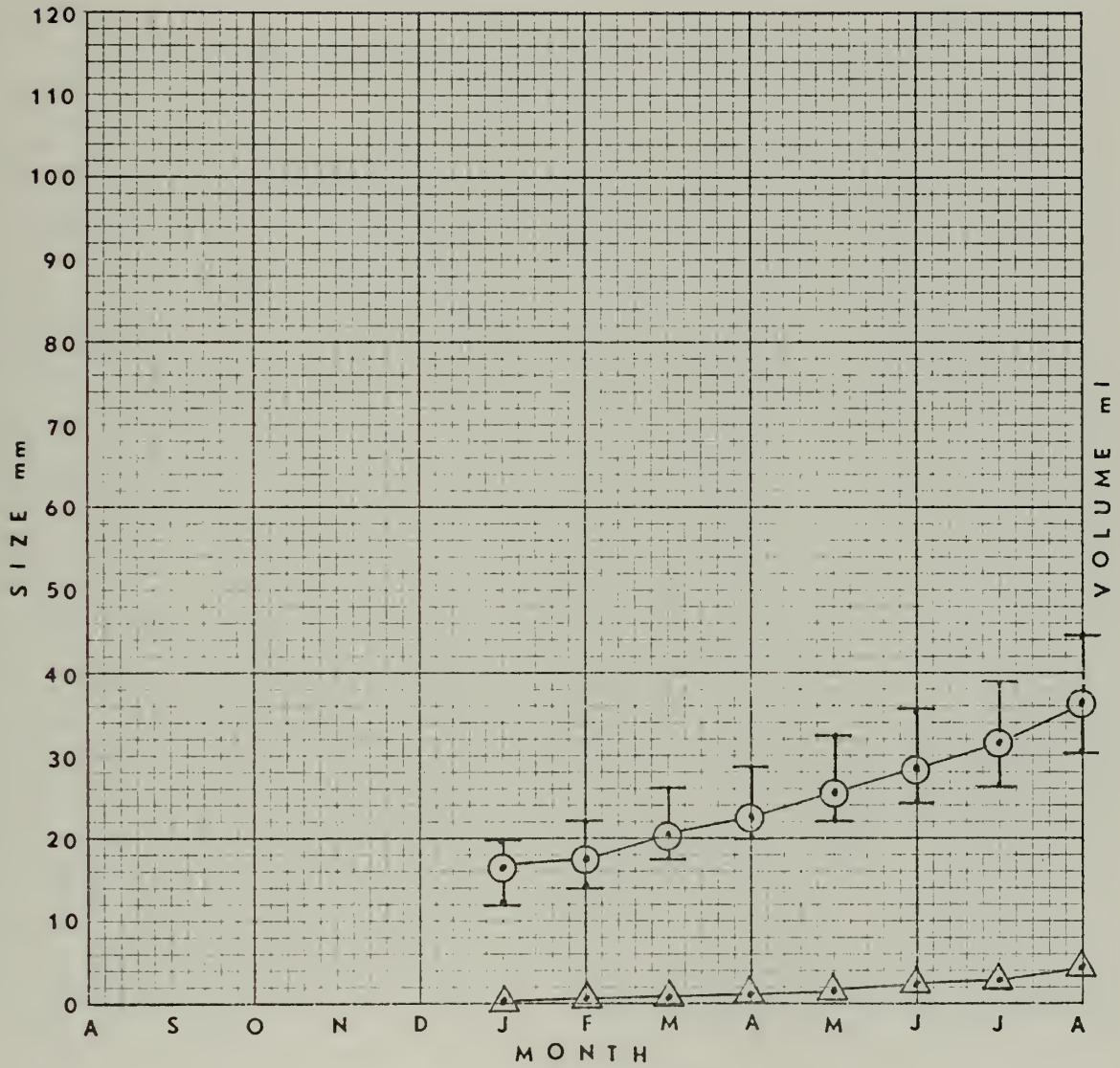

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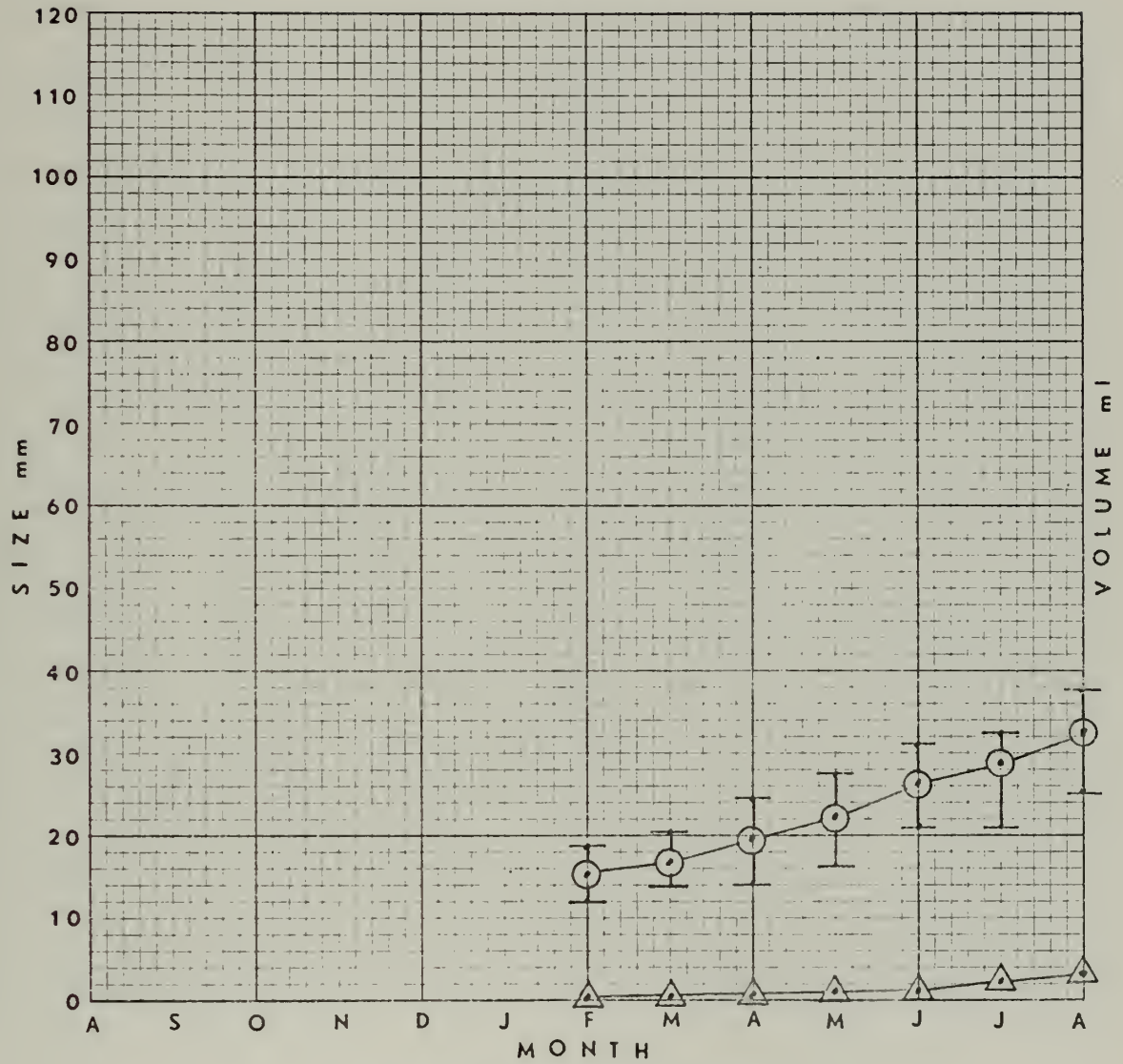

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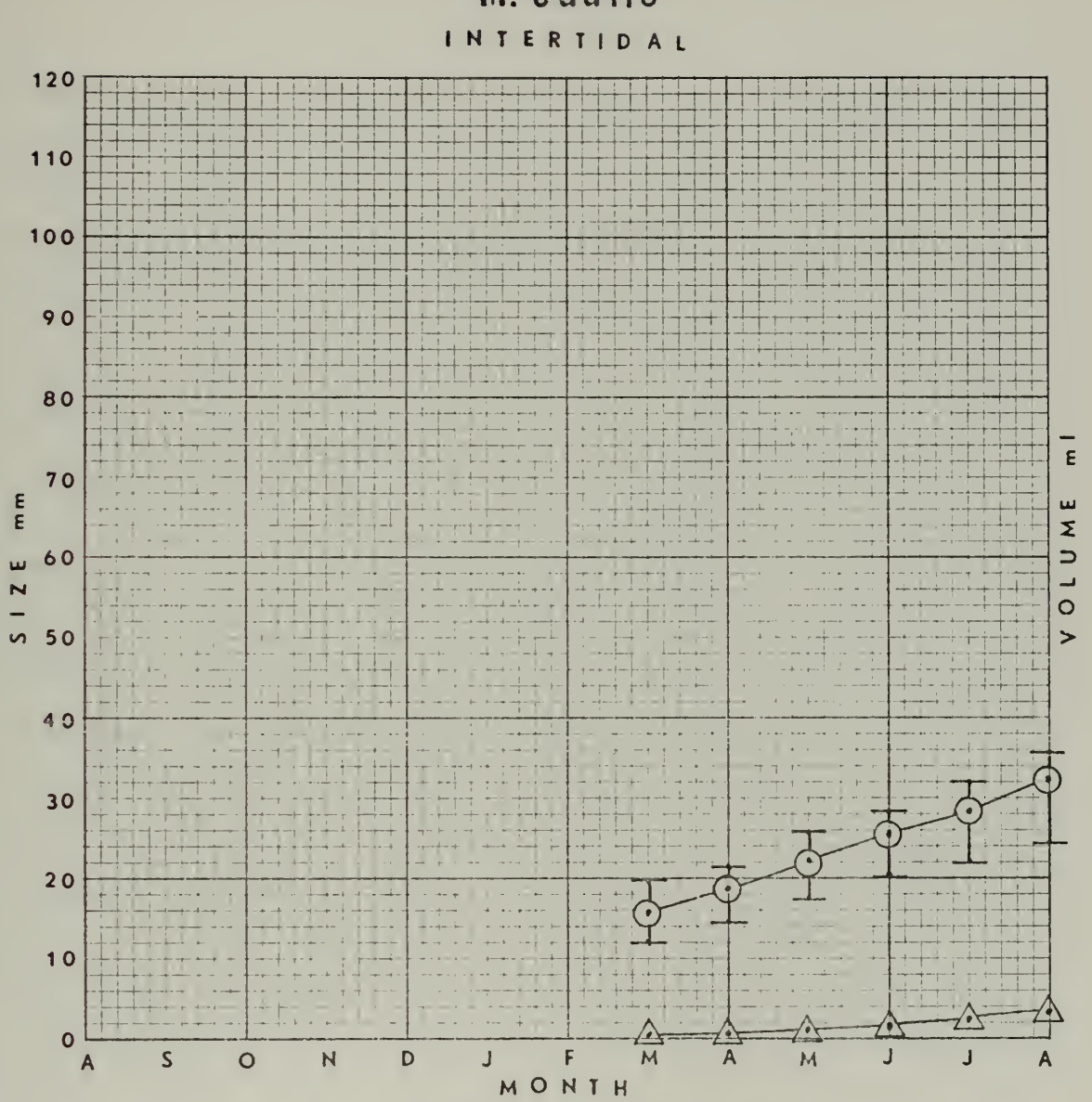

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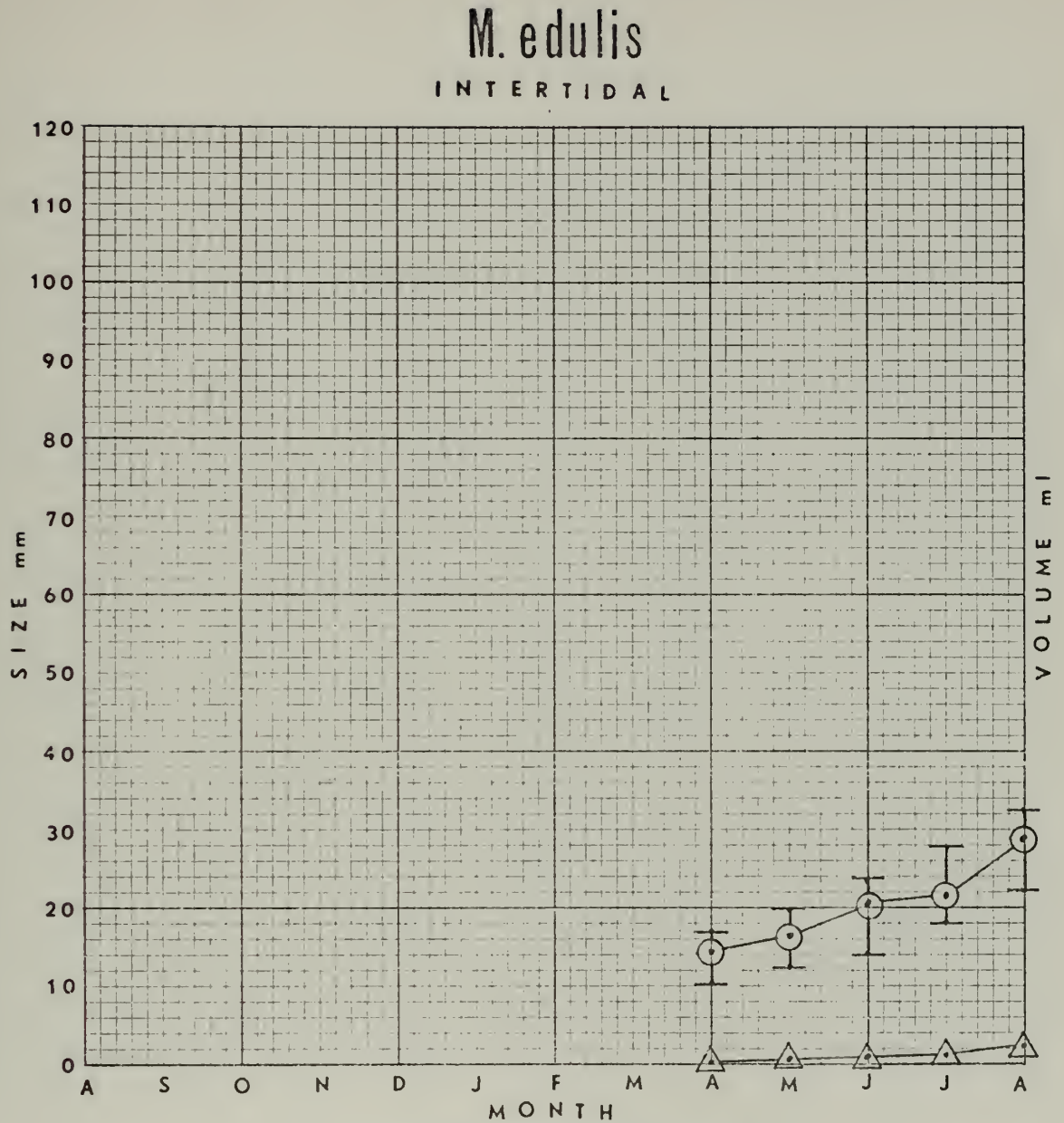

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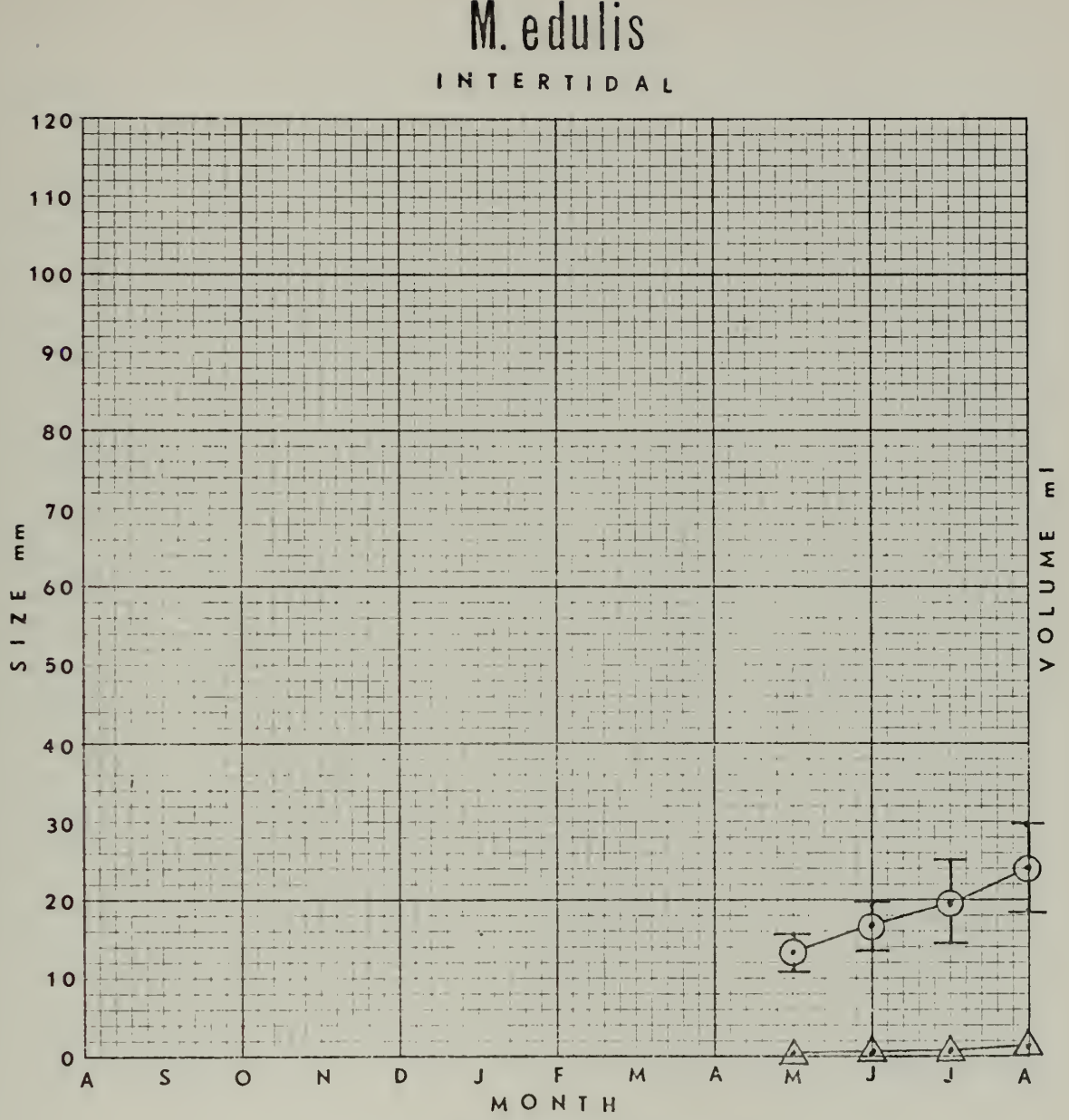

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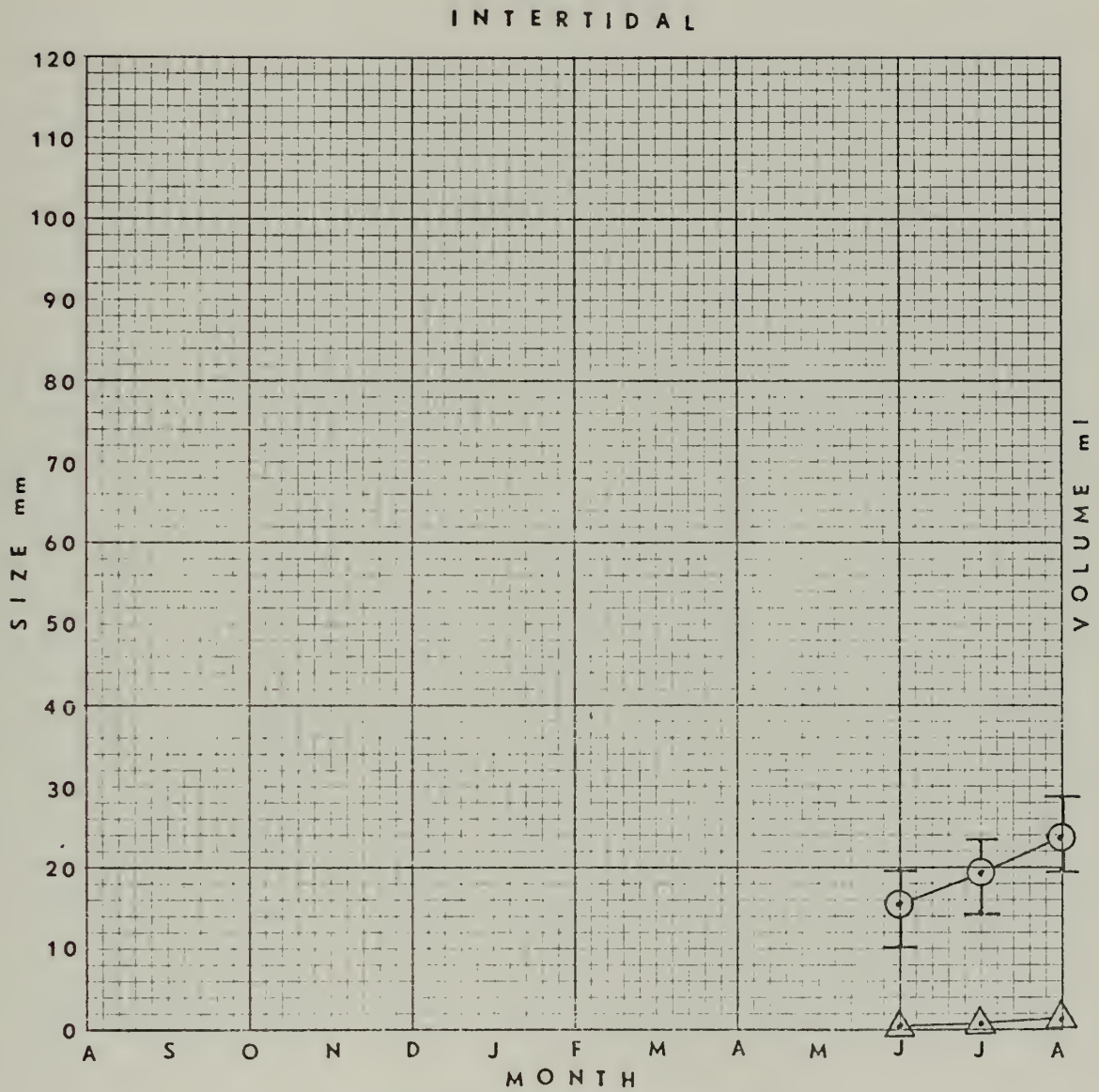

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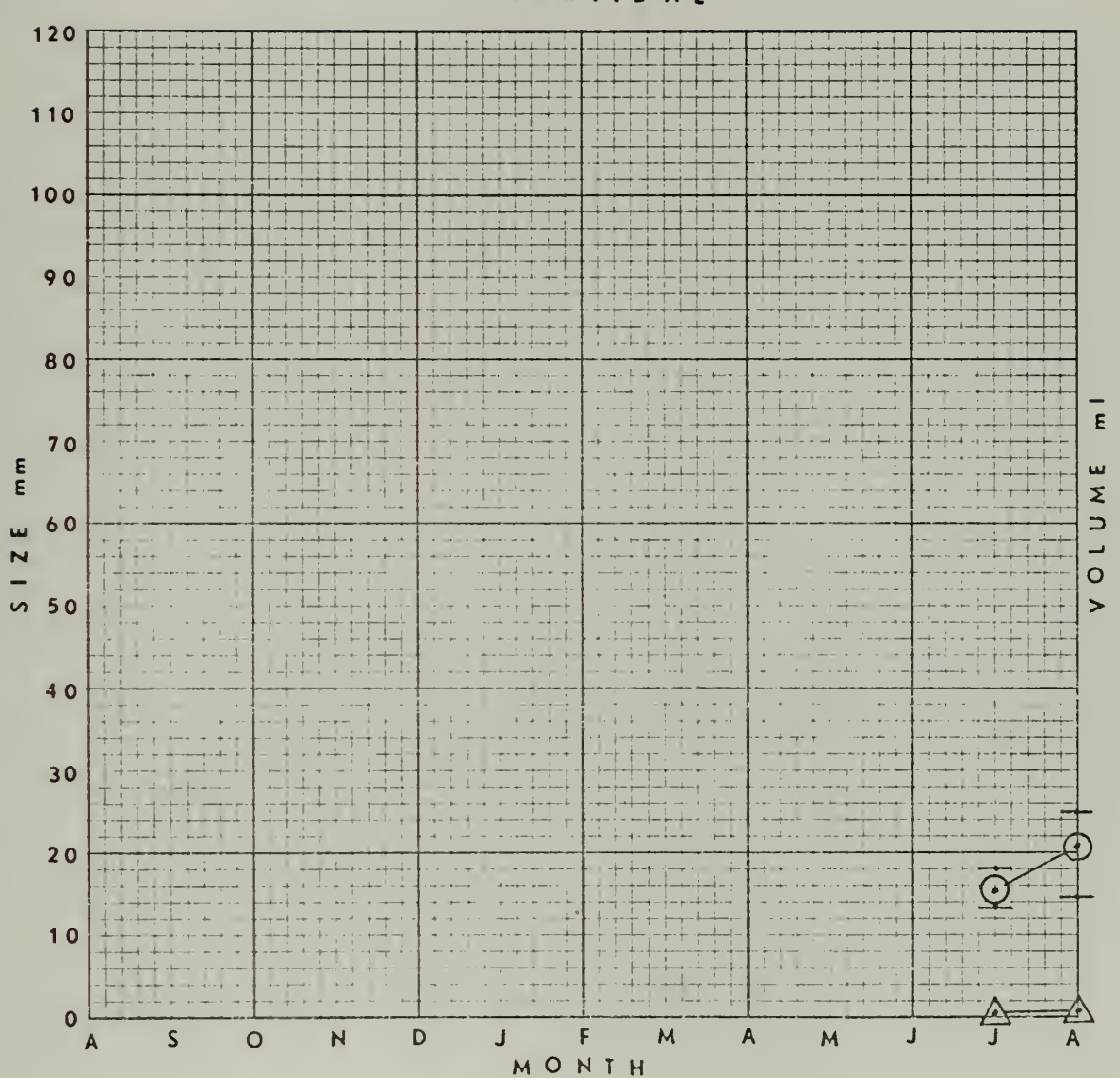

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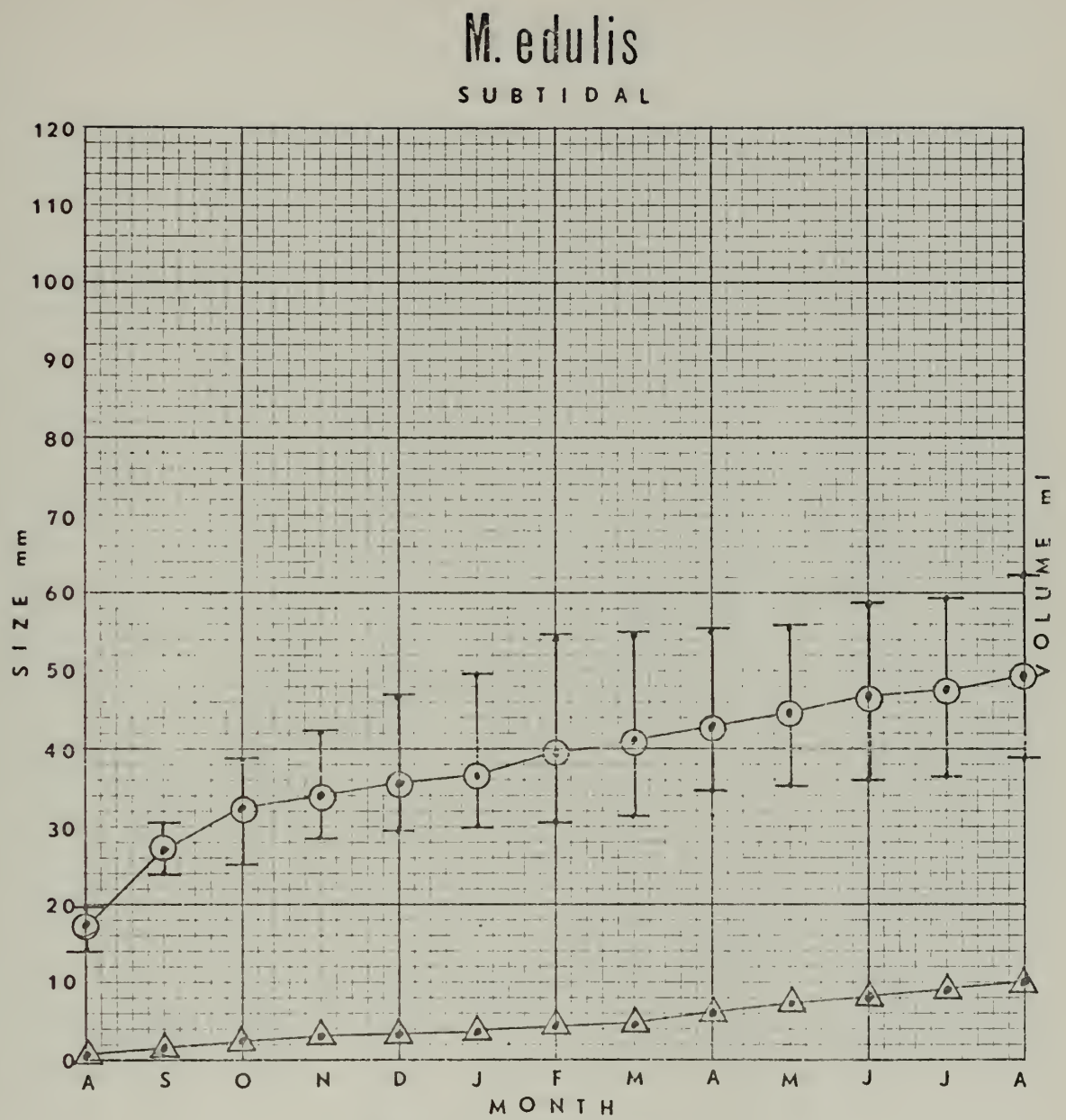

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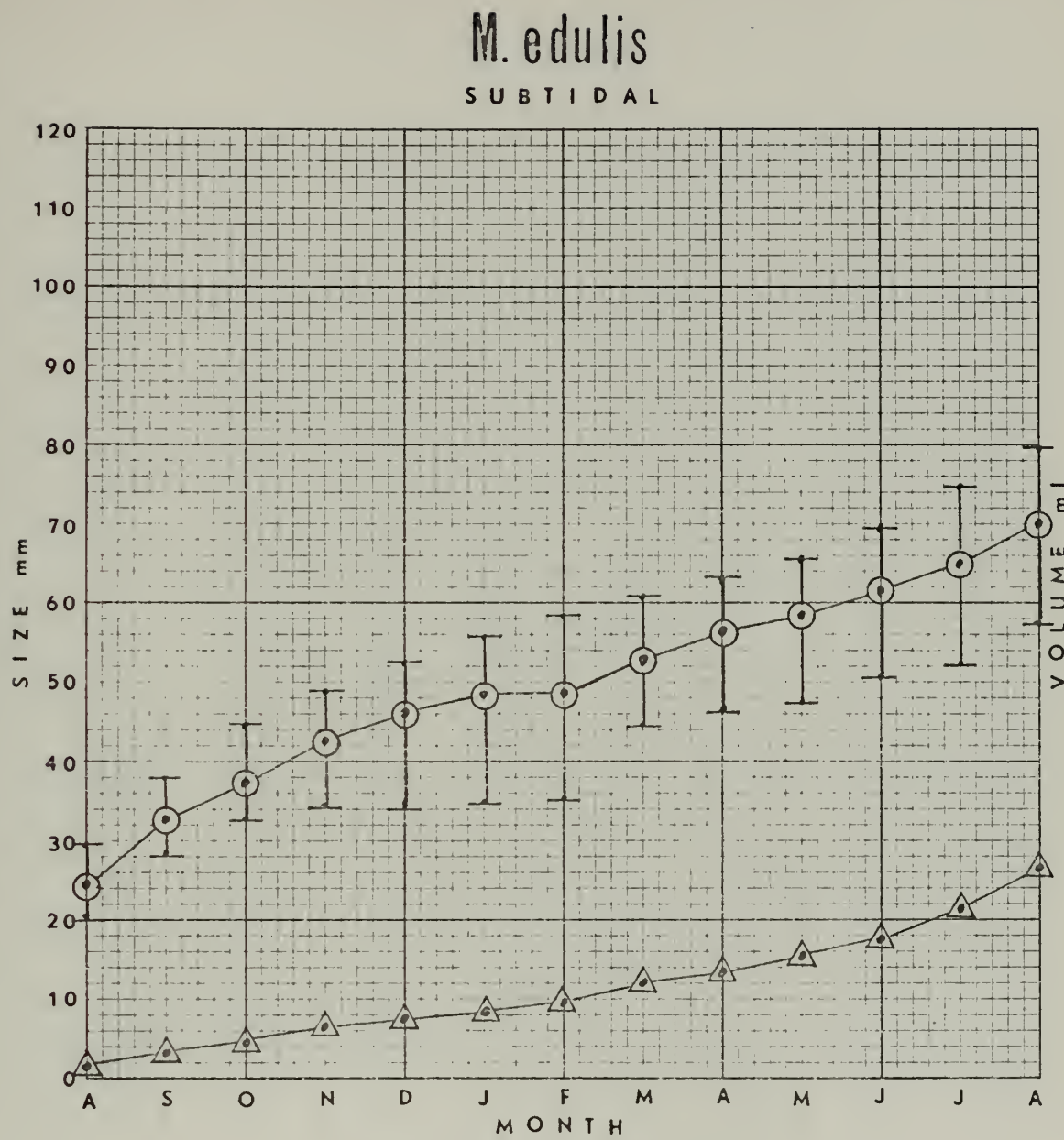

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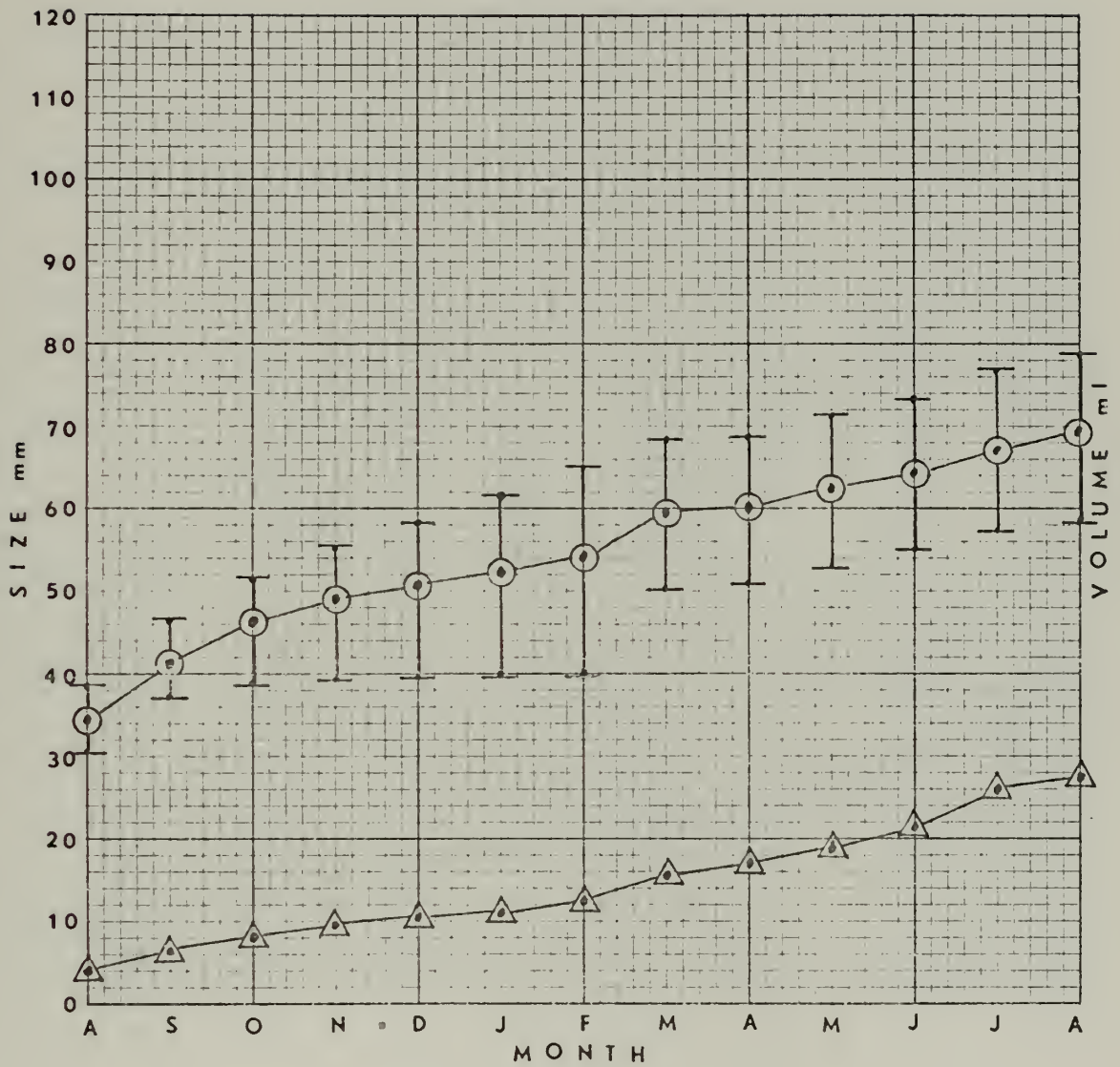

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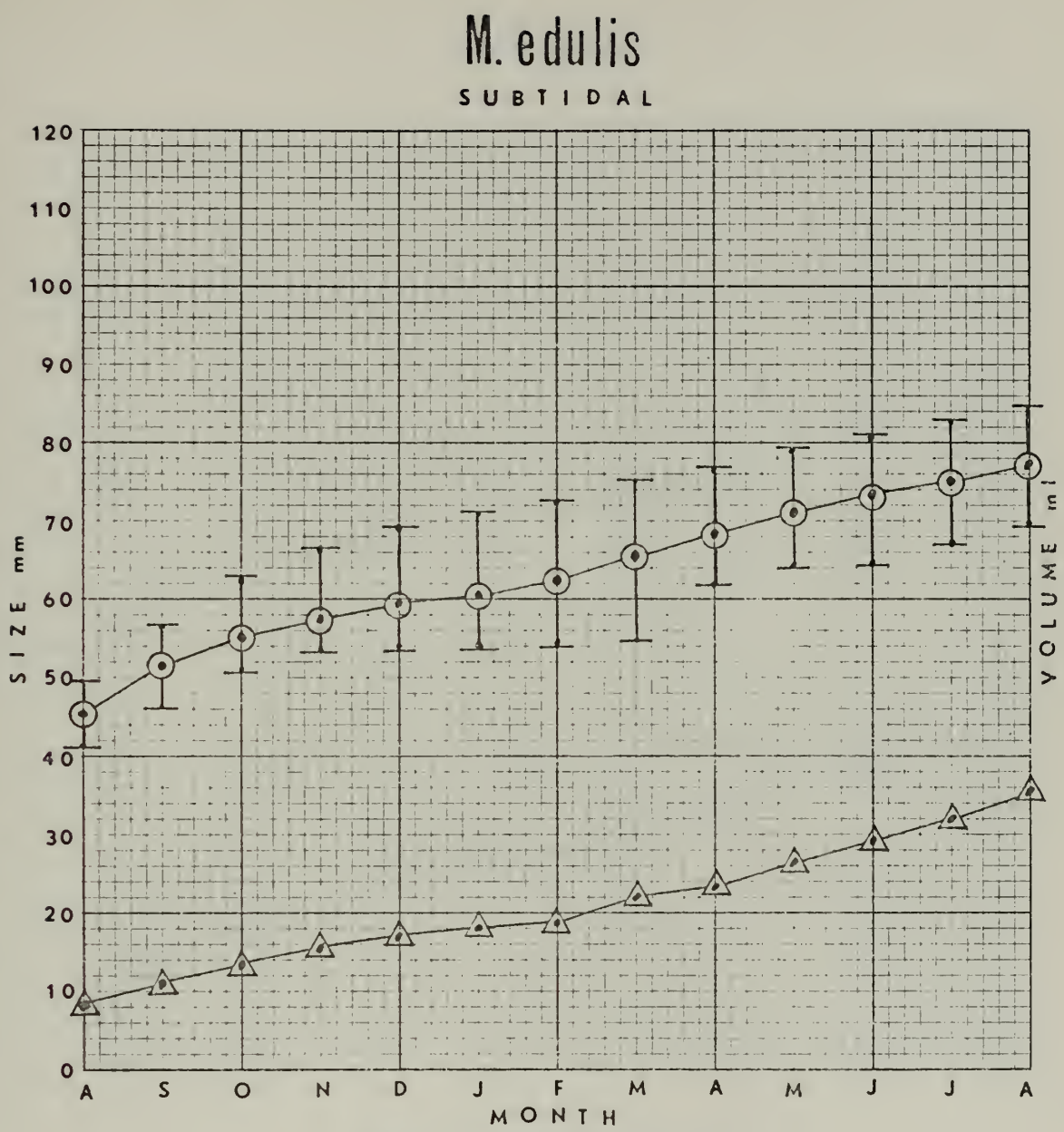

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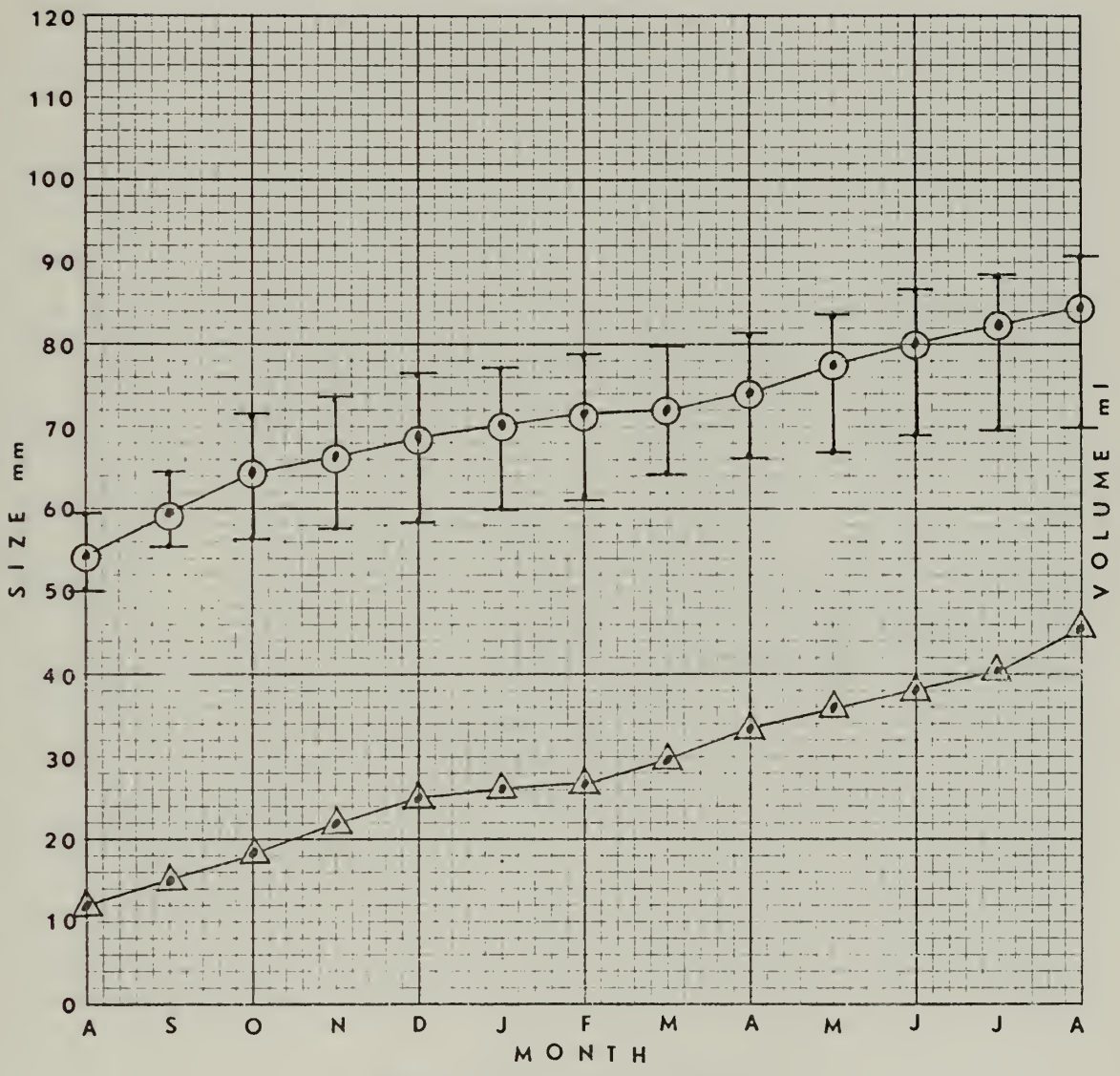

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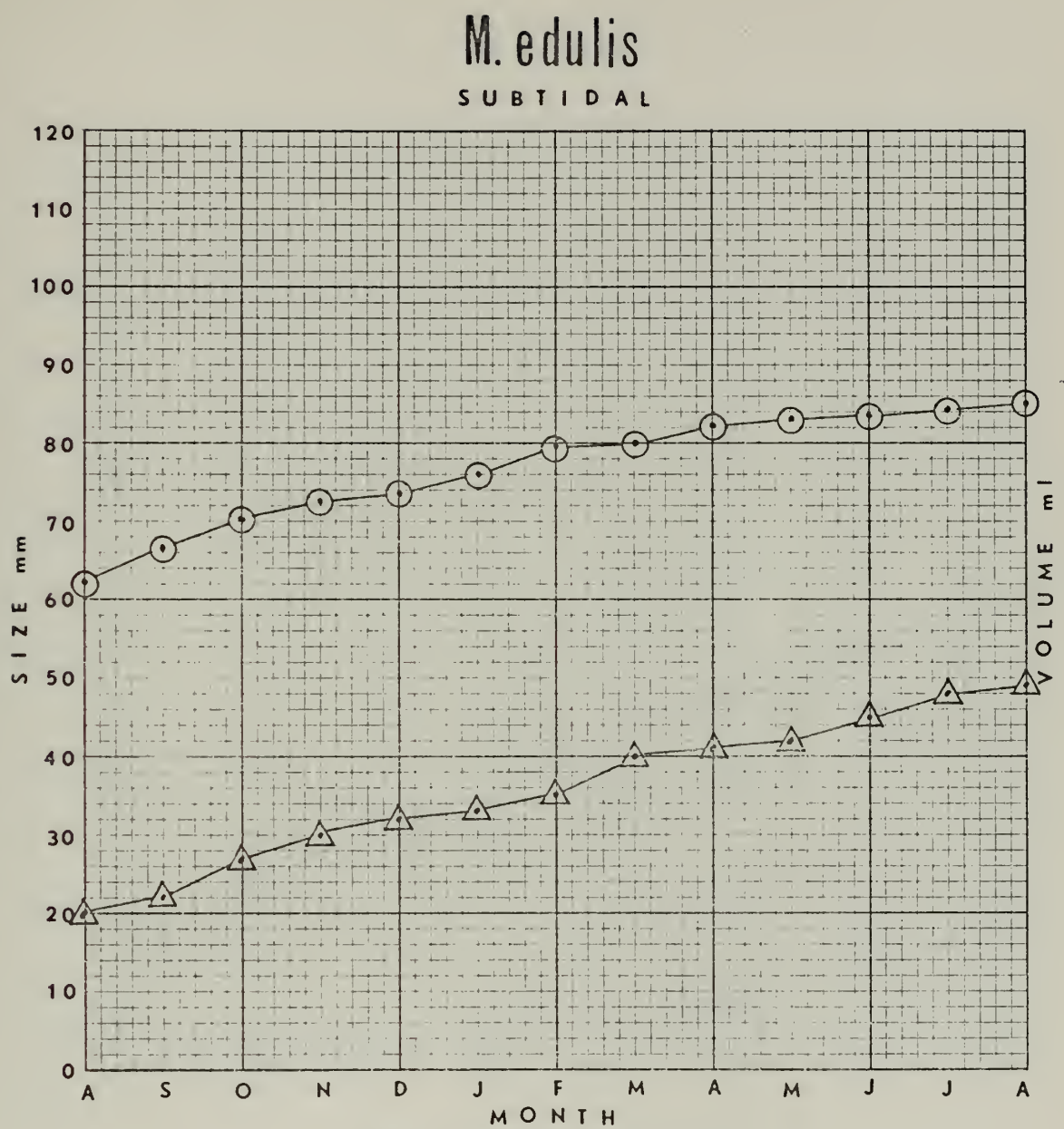

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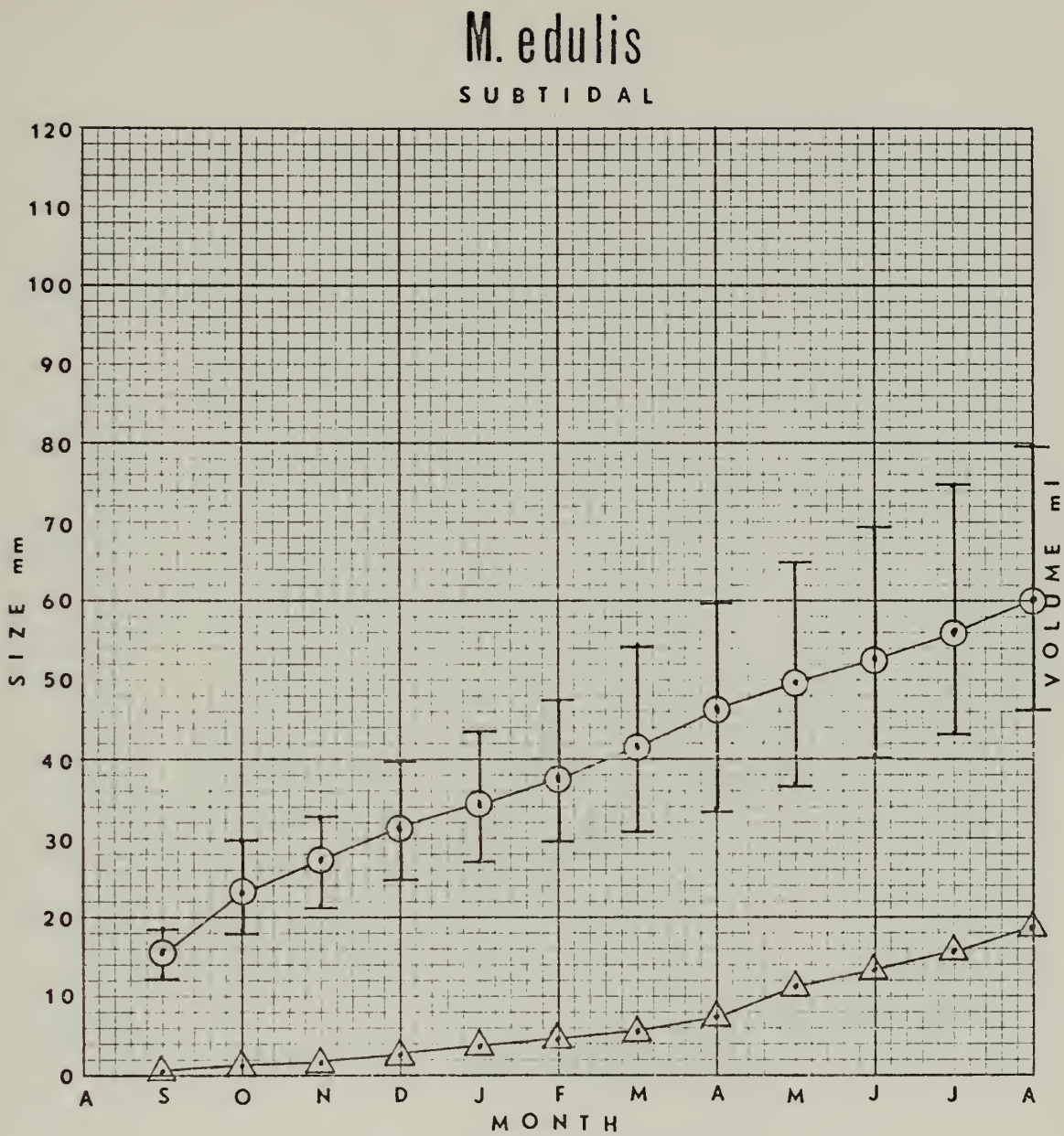

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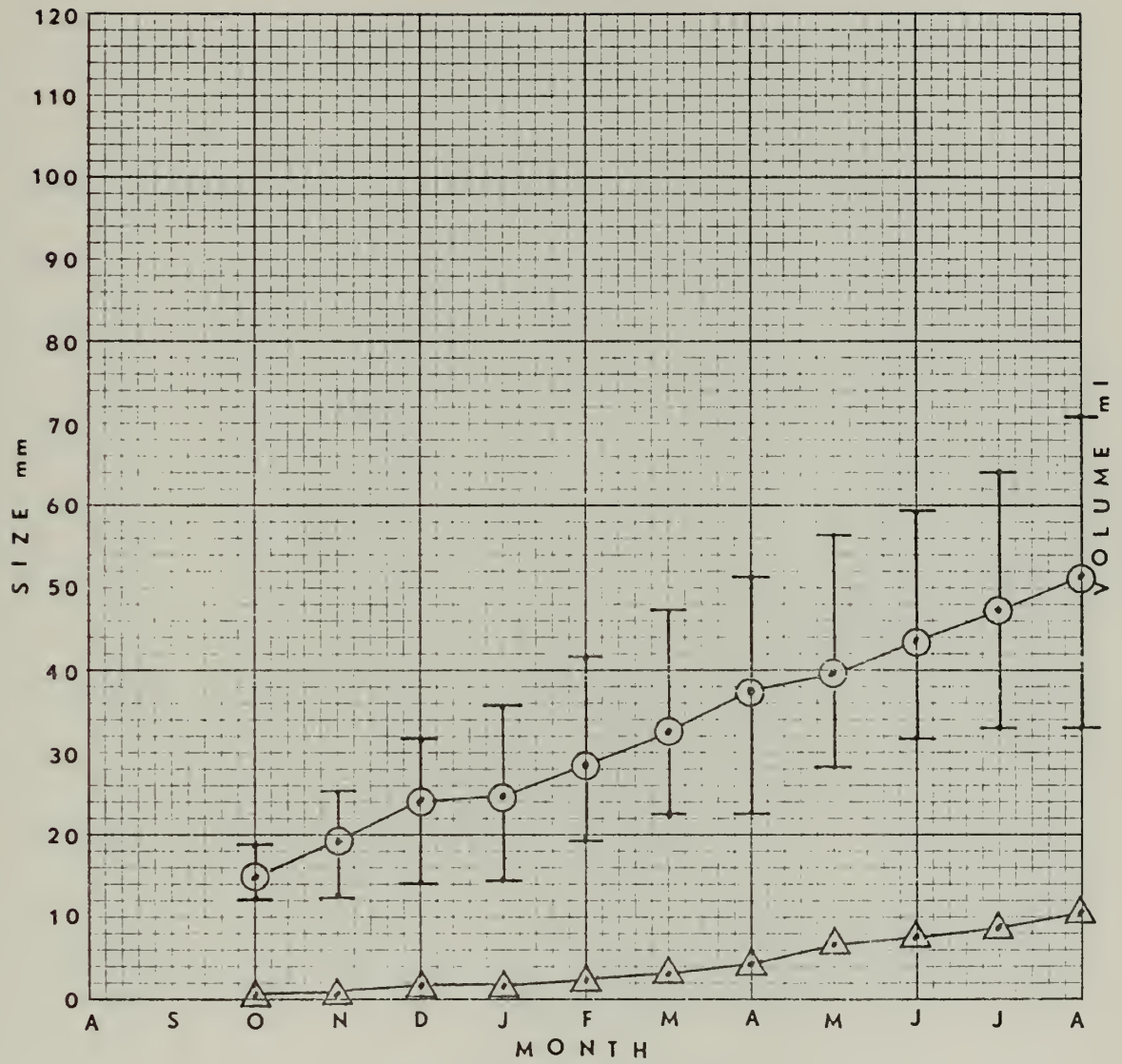

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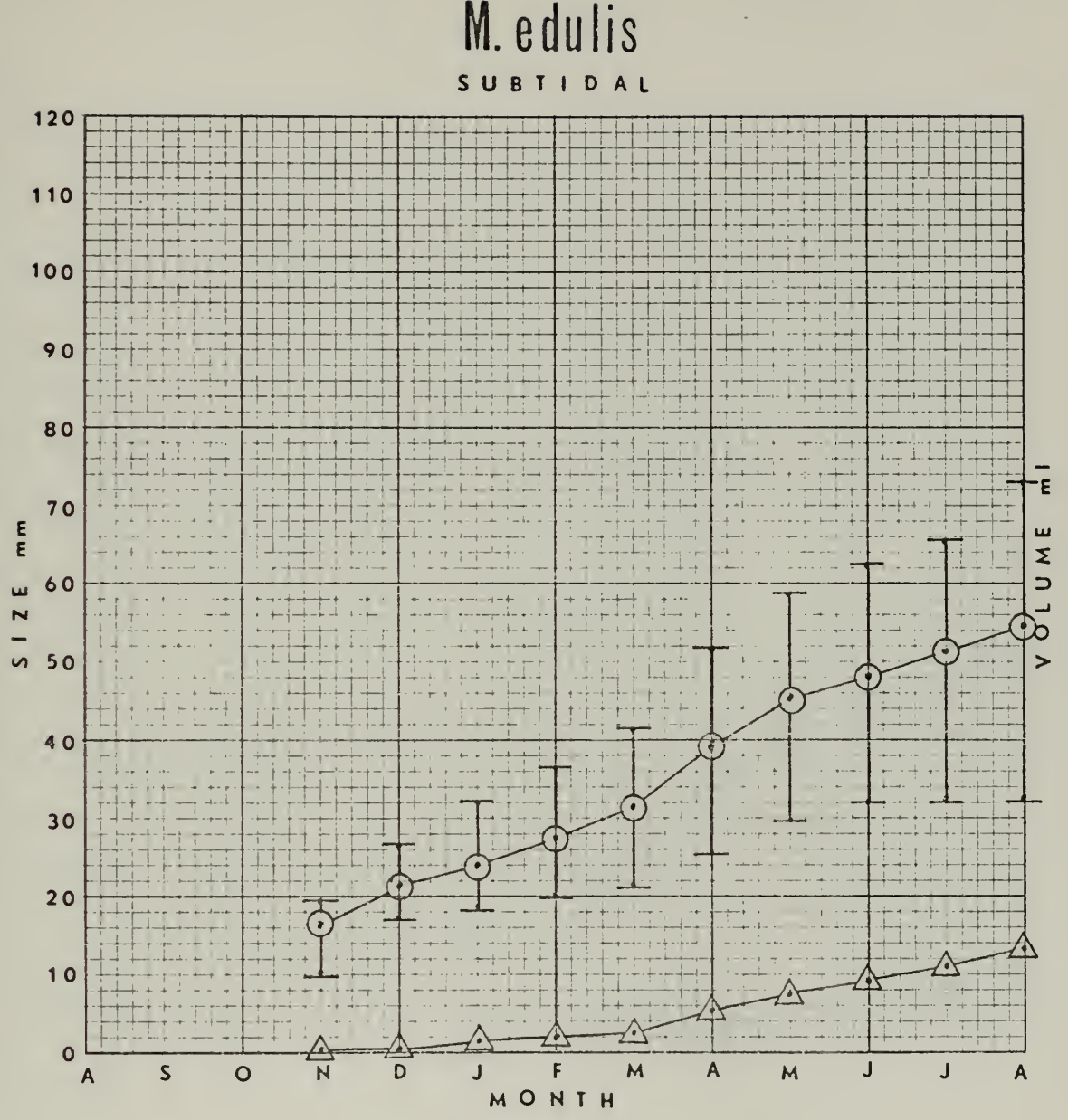

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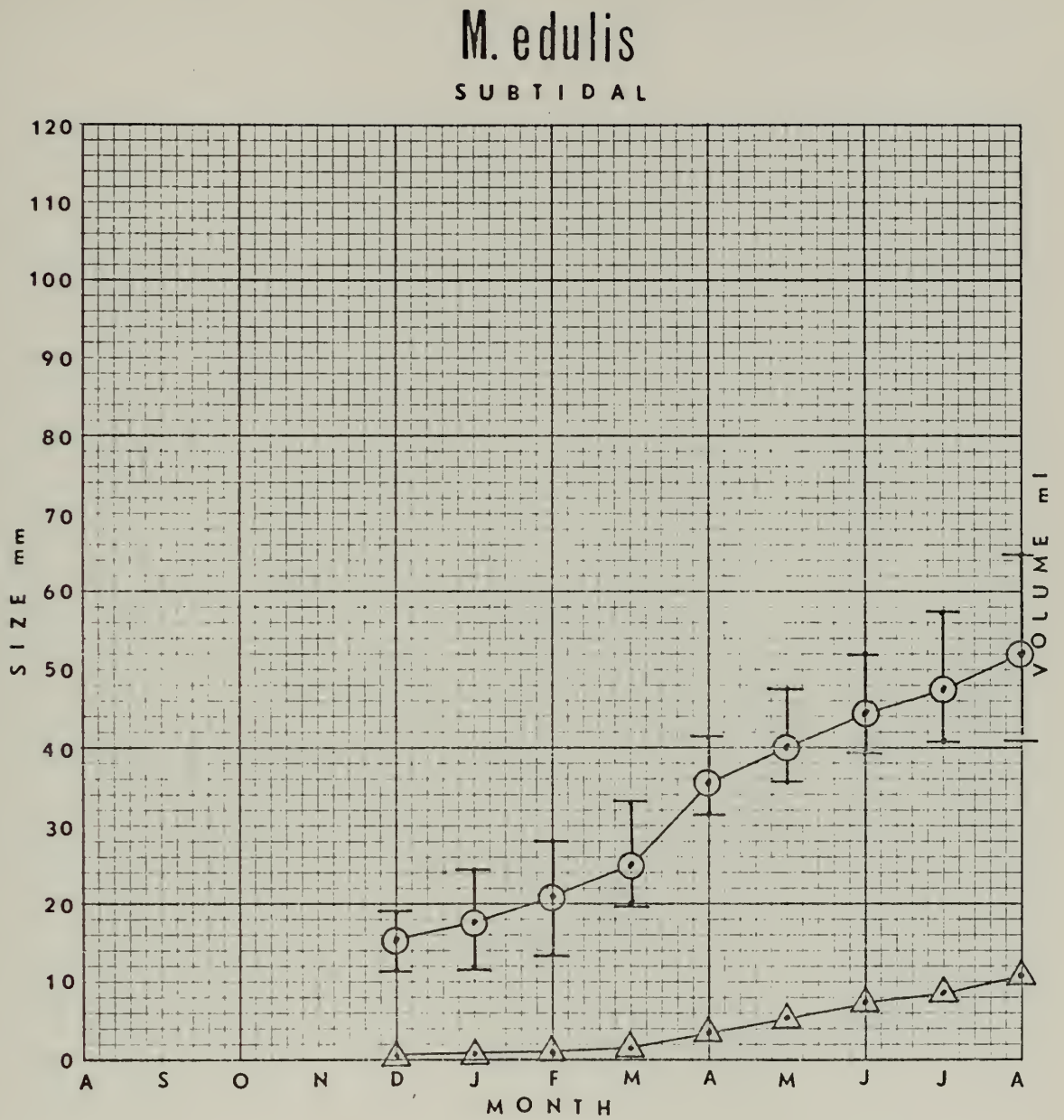

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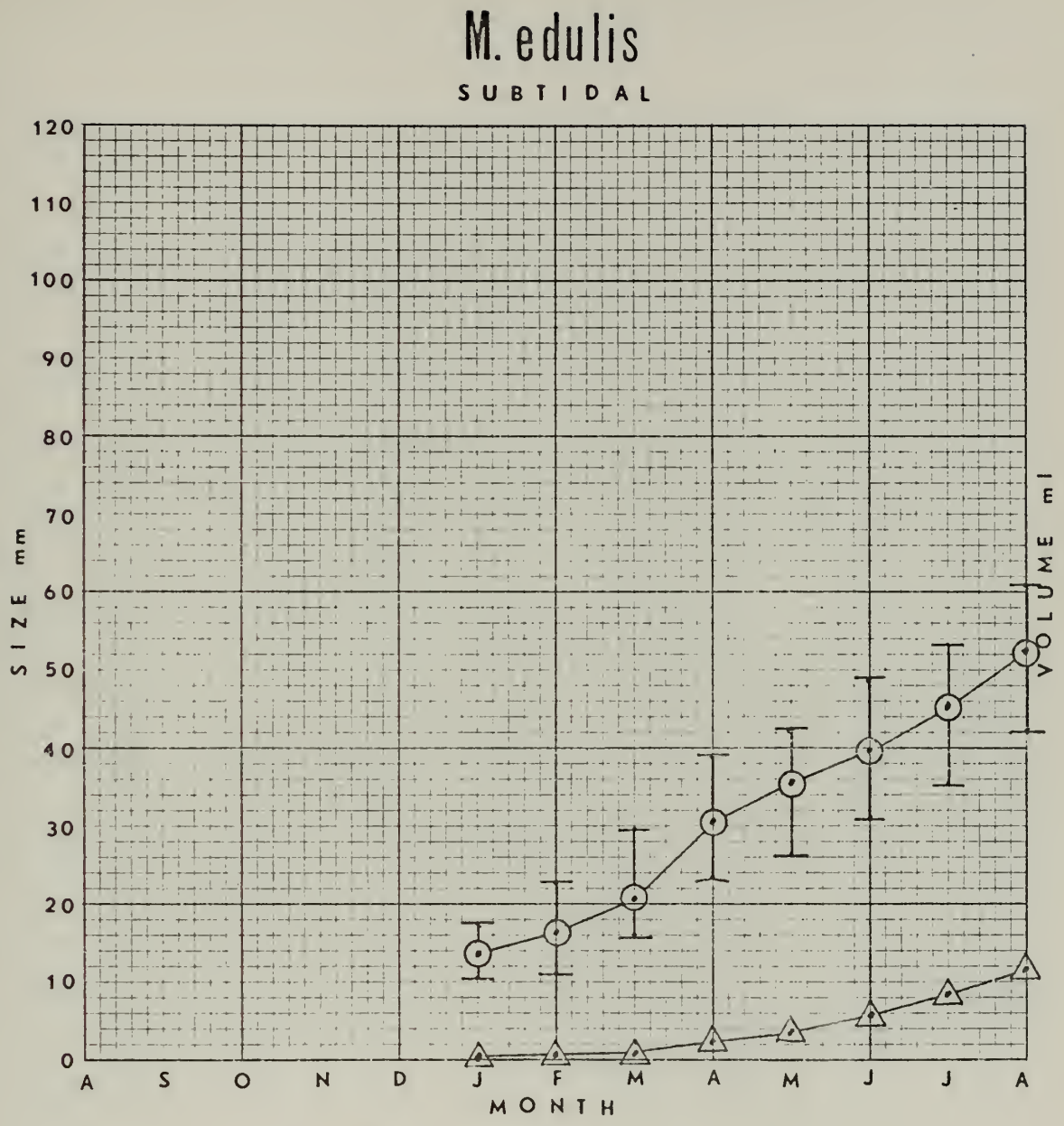

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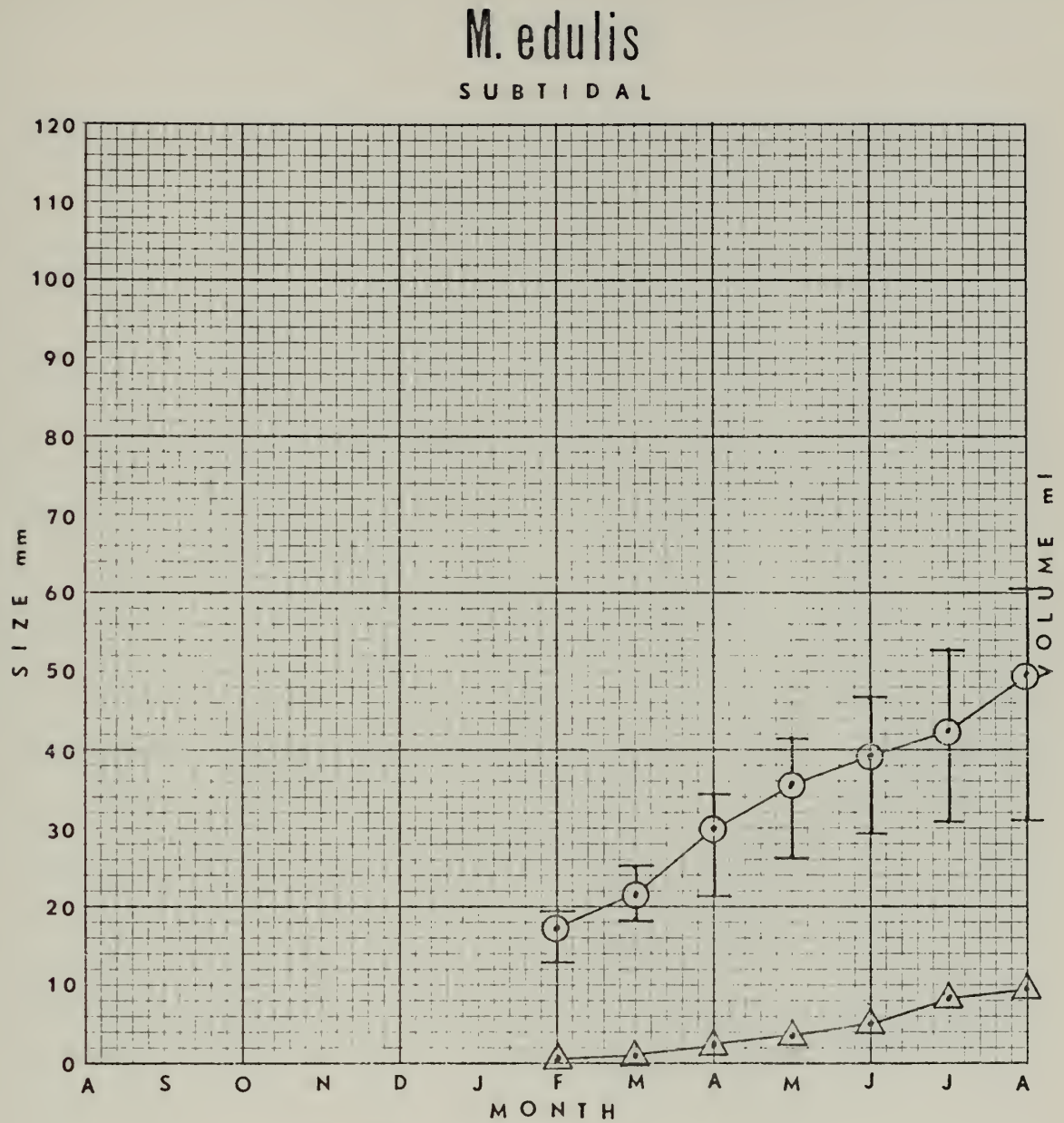

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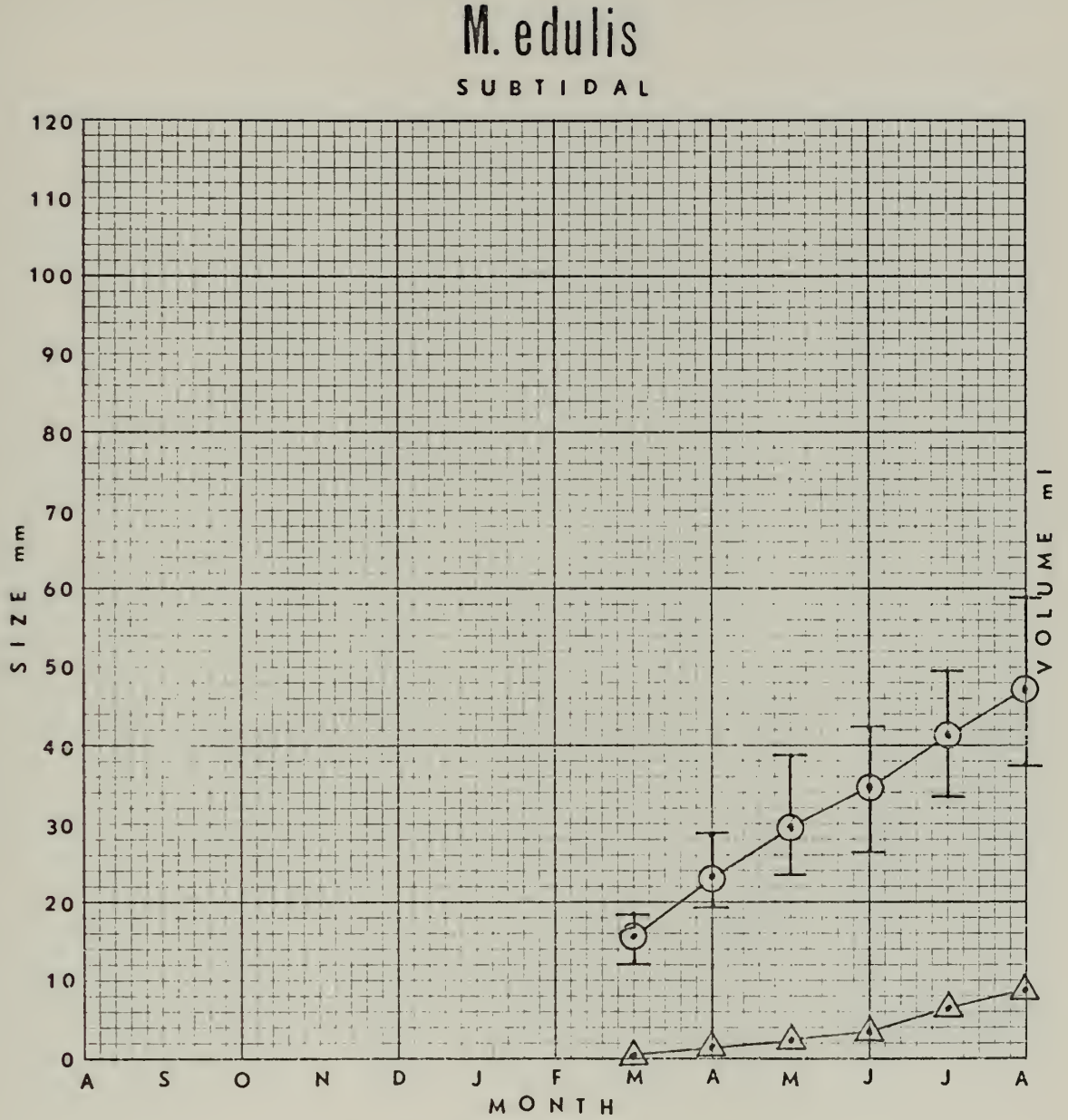

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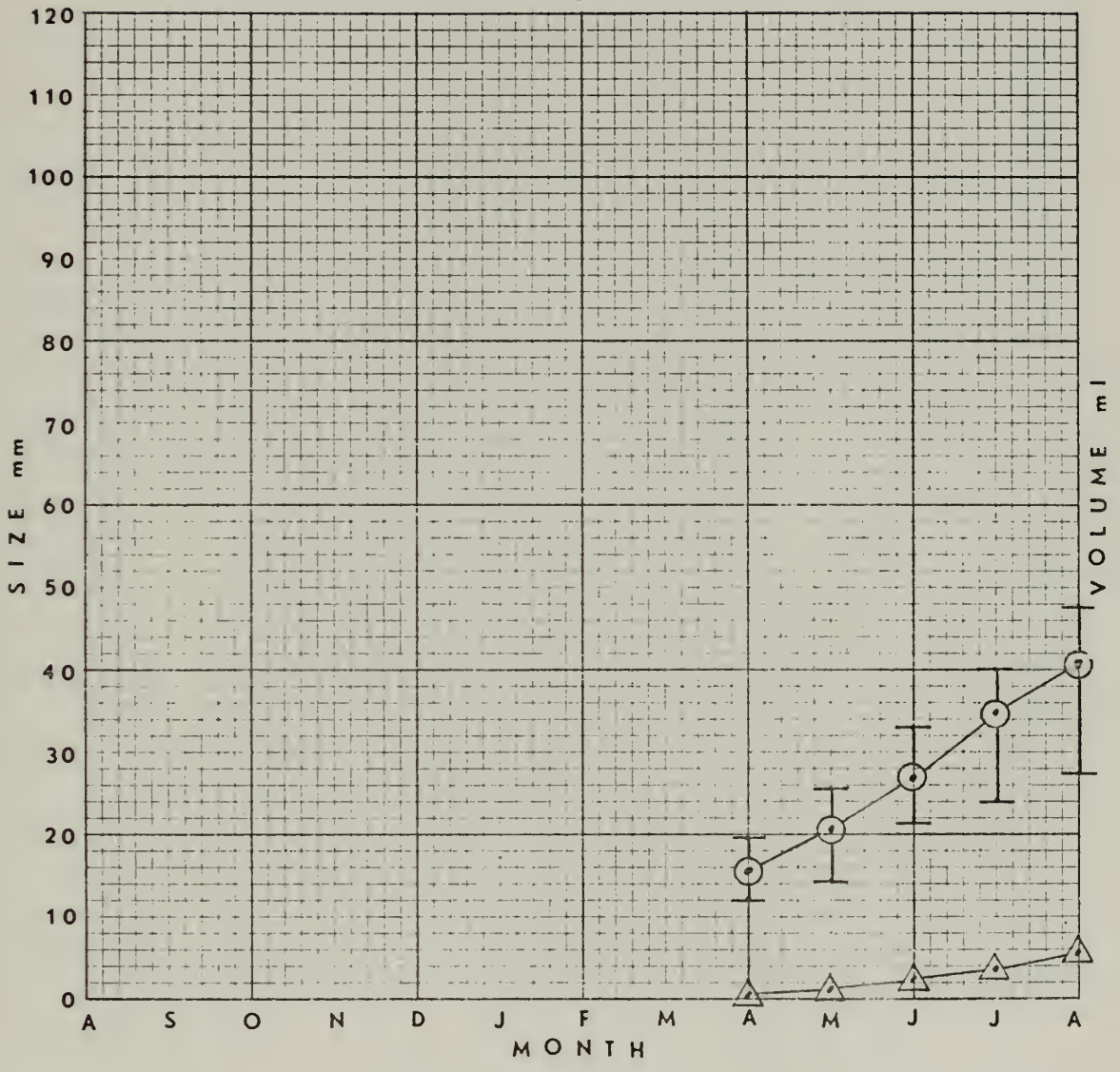

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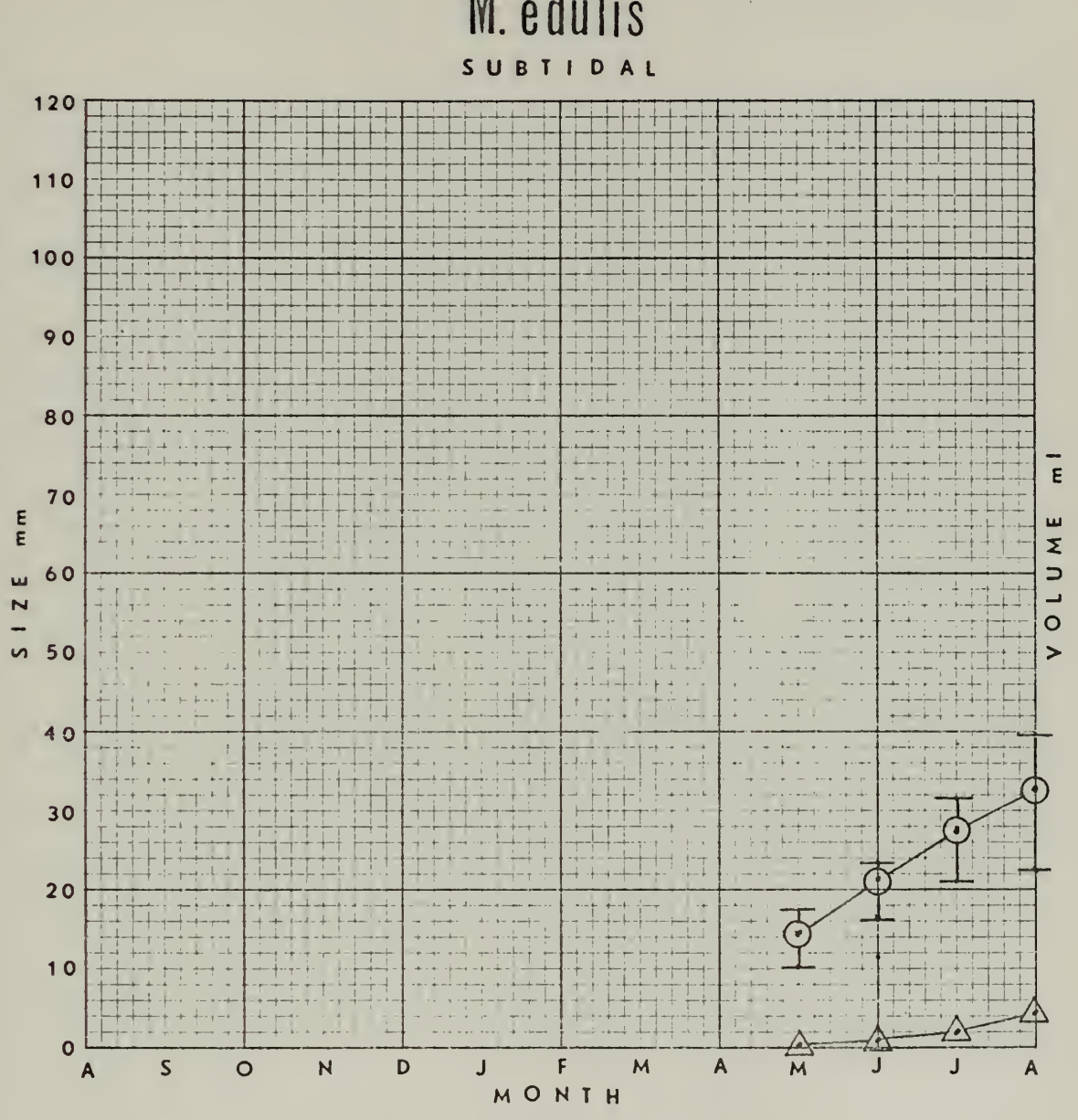

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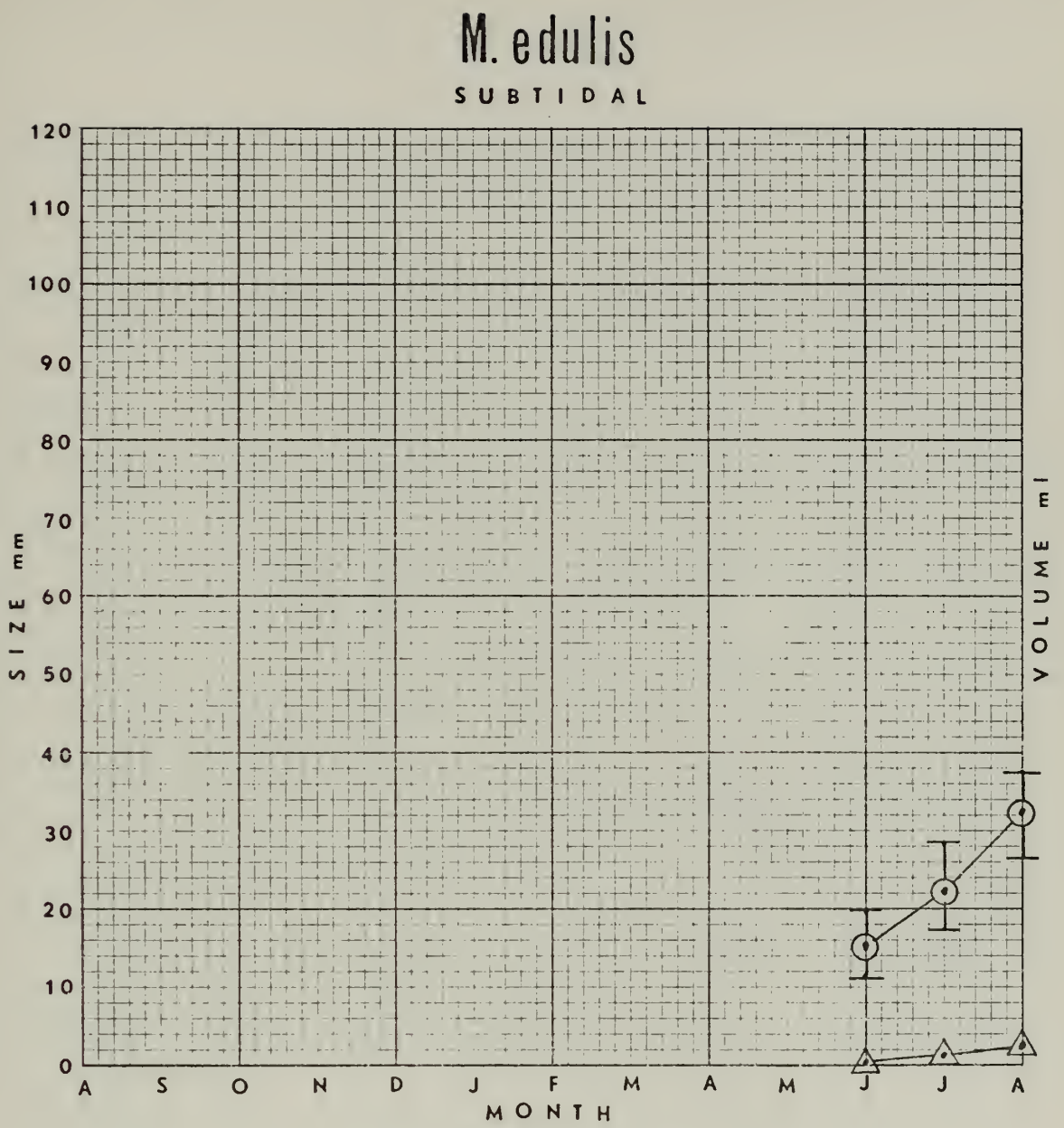

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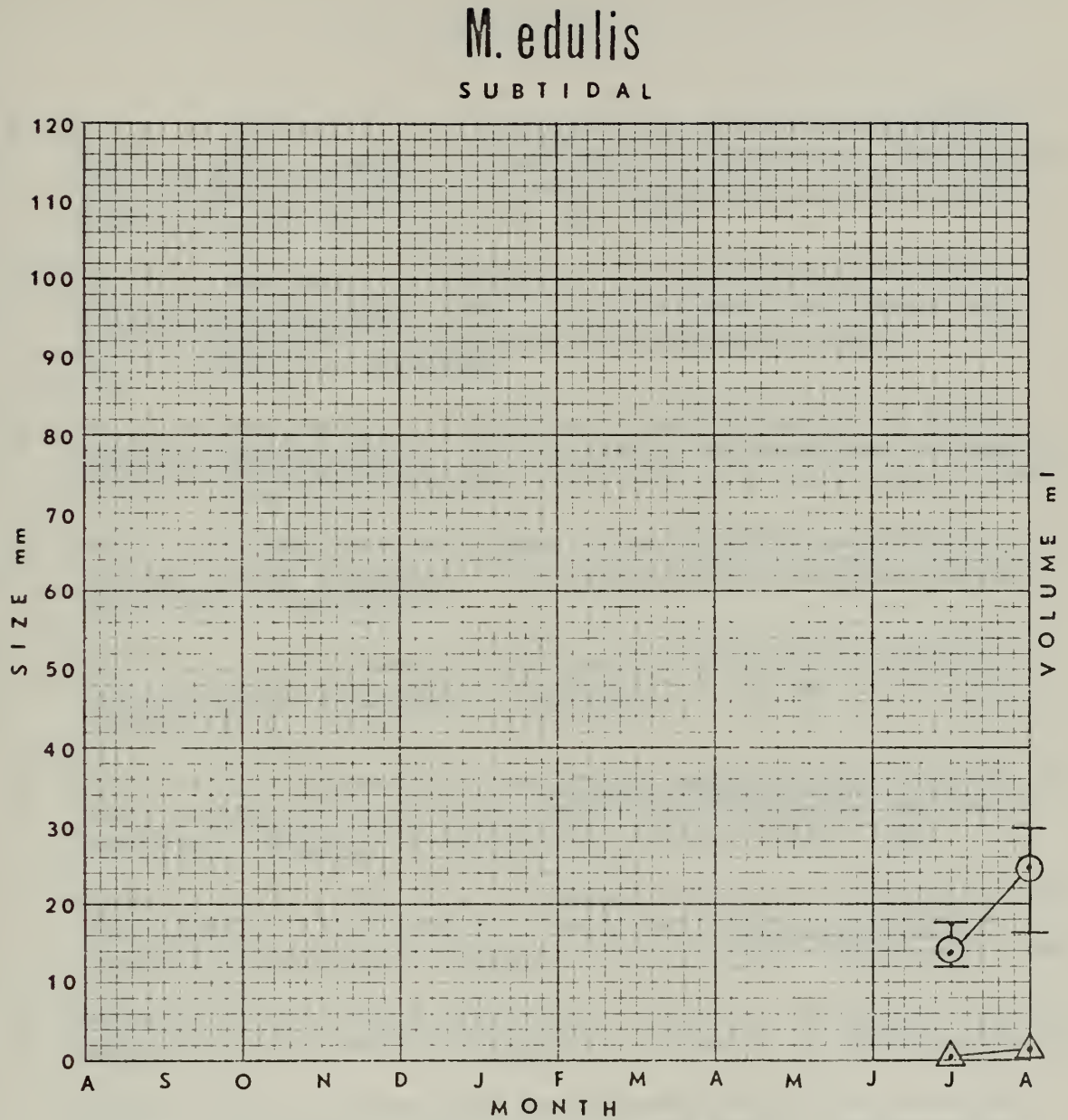

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BIBLIOGRAPHY

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author)
Naval Postgraduate School
Monterey, California 93940

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3 REPORT TITLE
MEASUREMENT OF THE GROWTH RATES OF MYTILUS CALIFORNIANUS AND MYTILUS EDULIS IN MONTEREY HARBOR

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)
Master's Thesis, September 1971

5 AUTHOR(S) (First name, middle initial, last name)
Robert E. Delgado

6. REPORT DATE
September 1971

7a. TOTAL NO. OF PAGES
105

7b. NO. OF REFS
9

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES

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13. ABSTRACT

Measurements of the growth rates of two species of sea mussel, Mytilus californianus and Mytilus edulis, were made in Monterey Harbor during the period August 1, 1970 to August 1, 1971. Mussel populations were housed in plexiglass-stainless steel cages and exposed to intertidal and subtidal conditions. Measurements of maximum length and average volume were taken at monthly intervals throughout the annual period.

Both species had a very close correlation between sea surface temperature and growth rate and demonstrated characteristic growth patterns for each species. There existed annual, seasonal, and monthly variation in the growth rates of both species as well as differences within different ages and sizes of each species.

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